WORKING DRAFT - PLEASE DO NOT DISSEMINATE

Re-framing birth cohort effects in the context of multi-level models: implications for time trends in adolescent alcohol and cigarette use in the United States

Katherine M. Keyes, PhD[1,2]
John E. Schulenberg, PhD[3]
Patrick M. O'Malley, PhD[3]
Lloyd D. Johnston, PhD[3]
Jerald G. Bachman, PhD[3]
Guohua Li, MD DrPH[1,4]
Deborah Hasin, PhD[1,2,5]

[1] Department of Epidemiology, Columbia University, New York, NY
[2] New York State Psychiatric Institute, New York, NY
[3] Institute for Social Research, University of Michigan, Ann Arbor, MI
[4] Department of Anesthesiology, Columbia University, New York, NY
[5] Department of Psychiatry, College of Physicians and Surgeons, Columbia University, New York, NY

Acknowledgements:
This research was supported in part by a fellowship from the National Institute on Drug Abuse (F31 DA026689, K. Keyes), grants from the National Institute on Drug Abuse (R01 DA001411, Johnston; R21 DA029670, Li), National Institute on Alcoholism and Alcohol Abuse (K05 AA014223, Hasin; R01 AA09963, Li), and support from New York State Psychiatric Institute (Hasin). We would like to thank Benjamin Feld for his assistance in these analyses.

Abstract:

The present study aimed to investigate whether adolescents in birth cohorts and/or time periods with high disapproval of alcohol and cigarette use were at decreased risk for alcohol and cigarette use, controlling for personal attitudes towards use and age. Data were drawn from the Monitoring the Future study, a nationally-representative annual survey of 8th, 10th, and 12th grade students conducted from 1976 through 2007. Social norms were measured by a period- and cohort-specific score incorporating the percentage of the population disapproval of alcohol and cigarette use. Cross-classified random effects models were employed with individuals clustered in time periods of observation and birth cohorts, and modeled period- and cohort-specific score on social norms as predictors in a multi-level modeling framework. Individuals who matured in disapproving cohorts were less likely to use alcohol compared to individuals who matured in less disapproving cohorts; each 5% increase in the disapproval of the birth cohort was associated with a 12% decrease in the odds of past-year alcohol use (OR=0.88, 99% C.I. 0.87-0.89). The effects of disapproval were notably stronger among White than non-White adolescents. In contrast, period-specific disapproval predicted cigarette use; each five percentage point increase in period-specific disapproval was associated with a 20% decrease odds (OR=0.81 99% C.I. 0.79-0.82). The present study documents the importance of considering time-varying population-level risk factors in the study of adolescent substance use, and suggests differing underlying processes for the impact of changing social norms on alcohol and cigarette use in adolescence.

Introduction

Adolescent use of alcohol and cigarettes is a substantial public health problem. While the prevalence of adolescent alcohol and cigarette use declined in recent years, in 2007 nearly three quarters of adolescents reported using alcohol by the 12th grade (Johnston, O'Malley et al. 2007), approximately half of high school seniors reported at least one binge drinking episode in their lifetime or use of cigarettes, and approximately 20% reported current daily cigarette use (Johnston, O'Malley et al. 2007). Public health research aiming to reduce and delay the uptake of cigarettes and alcohol has traditionally focused on identification of risk factors on the individual level (Sher 1994); however, evidence is accumulating that risk factors on multiple levels of organization are potentially important causes of alcohol and cigarette use (Galea, Nandi et al. 2004; Diez Roux 2007). This recognition has sparked innovative epidemiologic research with important public health implications (Galea, Nandi et al. 2004). Multi-level investigations have largely focused on characteristics unique to places; alcohol and cigarette use prevalences have exhibited substantial fluctuation over time (Johnston, O'Malley et al. 2007), however, suggesting that characteristics unique to time periods (e.g., policies, laws, economic conditions, social norms) may be potentially important causes of alcohol and cigarette use.

Multi-level studies of alcohol and cigarette use have documented that alcohol and cigarette use clusters geographically, and that characteristics of places (e.g., availability (Crum, Lillie-Blanton et al. 1996; Karvonen and Rimpela 1997), prices (Henderson, Liu et al. 2004), laws (Feighery, Altman et al. 1991; Schulte Gary, Aultman-Hall et al. 2003), media exposure (Farrelly, Davis et al. 2005), and neighborhood socio-economic indicators (Kleinschmidt, Hills et al. 1995; Duncan, Jones et al. 1999; Chuang, Cubbin et al. 2005; Datta, Subramanian et al. 2006; Ohlander, Vikstrom et al. 2006; van Lenthe and Mackenbach 2006; Chuang, Li et al. 2007)) appear to be important macro-level determinants of individual use among both adolescents and adults. Multi-level analyses have also documented that factors associated with schools, such as larger size (Johnston 1973) and anti-smoking policy (French, Porter et al. 1982; Pentz, Brannon et al. 1989; Pinilla, Gonzalez et al. 2002), predict cigarette initiation among adolescents. However, the characteristics unique to certain time periods as potential macro-level causes of alcohol and cigarette use have received little attention in a multi-level framework. Further, the effects of changing social norms, a macro-level construct and potentially important determinant of individual-level behavior (Fishbein and Ajzen 1975) has received little attention in a multi-level framework.

Social norms have long been an important component of sociological and psychological models of adolescent alcohol and drug use (Fishbein and Ajzen 1975; Ajzen 1991; Baranowski, Perry et al. 1997). Social norms regarding alcohol and cigarette use have been defined heterogeneously, but broadly refer to the acceptability of use by a salient reference group (e.g., peers, school, or community). However, social norms have mostly been operationalized in terms of individual-level adolescent perceptions of the social norms attitudes of those around them (Tyas and Pederson 1998; Fagan, Eisenberg et al. 2001; Eisenberg and Forster 2003; Komro, McCarty et al. 2003). These perceptions, however, may be inaccurate. For example, evidence indicates that substance users perceive their environment (e.g., neighborhood, community, school) to be riskier than do non-users in the same environments (Blount and Dembo 1984; Dembo, Blount et al. 1986; Nurco, Kinlock et al. 1996; Yarnold and Patterson 1998; Perkins, Meilman et al. 1999). Thus, using perceptions of social norms as proxies for norms, rather than objective measures of the normative climate, may introduce differential misclassification that magnifies the relation between norms and substance use (Wilcox 2003). Further, extant research largely captures variation in social norms in alcohol and cigarette use across places (e.g., neighborhoods (Chuang, Ennett et al. 2005; Ahern, Galea et al. 2009),

schools (Ennett, Flewelling et al. 1997)); however, changes in social norms across time periods (Greenfield and Room 1997) may be an important source of variation to predict alcohol and cigarette use, given the substantial fluctuation in alcohol and tobacco prevalence over time (Johnston, O'Malley et al. 2007). Available evidence suggests that indicators of social norms such as perceived risk and disapproval explain changes in the prevalence of marijuana use over time (Bachman, Johnston et al. 1998), indicating that time trends in social norms may be important determinants of use at the population level.

Age-period-cohort (APC) models are the most commonly used analytic technique to examine trends in alcohol and cigarette use (O'Malley, Bachman et al. 1984; O'Malley, Bachman et al. 1988; Anthony, Warner et al. 1994; Chen, Li et al. 2003; Chassin, Presson et al. 2007; Keyes, Li et al. under review). APC models have consistently identified cohort effects in alcohol consumption as well as alcohol disorders and mortality, both in the U.S. and elsewhere (reviewed in (Keyes, Li et al. under review)). Results from APC models of cigarette use have been mixed; while studies of lung cancer mortality (a potential proxy measure for long-term cigarette smoking), have consistently documented cohort effects (Strand, Malayeri et al. 2004; Shibuya, Inoue et al. 2005; Eilstein, Uhry et al. 2008), some studies of adults and adolescents have documented a cohort effect (O'Malley, Bachman et al. 1984; O'Malley, Bachman et al. 1988; Anthony, Warner et al. 1994; Chassin, Presson et al. 2007) whereas others have not (Chassin, Presson et al. 2007; Degenhardt, Chiu et al. 2007). Further, results vary by outcome measure, analytic strategy, and study location. Importantly, existing statistical models of age, period, and cohort effects largely fail to test mechanisms through which effects arise, regardless of outcome measure (Winship and Harding 2008). While the documentation of age, period, and cohort effects is an essential tool to begin understanding temporal variation, testing hypotheses about the mechanisms through which these effects occur is essential if these effects are to be better understood (Mannheim 1952; Ryder 1965; Winship and Harding 2008). No previous study of age-period-cohort effects in alcohol and cigarette use has tested hypotheses about the mechanisms through which age, period, and cohort effects may arise.

The present analysis extends prior work in these data examining trends in the relationship between social norms and adolescent substance use (Bachman, Johnston et al. 1998), investigating whether social norms with regard to alcohol and cigarette smoking across age, period, and cohort over time predict use of alcohol and cigarettes among adolescents utilizing nationally-representative data collected from 1976-2007 from the Monitoring the Future study. I define social norms regarding alcohol and cigarette use at the population-level rather than individual-level to mitigate misclassification due to inaccurate adolescent perceptions, and control for individual-level attitudes and perceptions of social norms regarding alcohol and cigarette use to examine whether there is a direct effect of norms that is unmediated by adolescent attitudes and perceptions. For both alcohol and cigarette use, I also examine whether socio-demographic characteristics such as sex, race/ethnicity, and highest level of parental education modify the effect of social norms.

Methods

Study and collection of data

The Monitoring the Future (MTF) survey (Monitoring the Future) is a yearly cross-sectional survey of approximately 130 U.S. public and private high schools, conducted during the spring semester. High schools were selected under a multi-stage random sampling design. Schools were invited to participate for a maximum of two years, and participation rates range from 95% to 99% for all study years. Schools that declined participation are replaced with schools matched on geographic location, size, and urbanicity. Starting in 1975, approximately 15,000

12th graders were sampled annually. In 1991, 8th and 10th graders were added, with approximately 17,000 and 15,000 students sampled, respectively. Student response rates ranged from 77% (1976) to 91% (1996, 2001, 2006). Almost all non-response was due to absenteeism; less than 1% of students refused to participate.

Survey administration was carried out by trained representatives of the local Survey Research Center in the geographic area of the school. Self-administered, sealed questionnaires were given to students, typically in classroom settings with a teacher present. Teachers were instructed to avoid close proximity to the students during administration to ensure students could respond confidentially.

Sample for analysis

Assessment of age, period, and birth cohort. Data were provided to the investigators on the three modal ages within each survey year and grade. Thus, a total of three ages (age 17, 18, and 19) were available from 1976-1990, and seven ages (age 13-19) from 1991-2006. Within each grade, 95% of students fell into three birth years. Detailed description of design and procedures are provided by MTF publications (Johnston, O'Malley et al. 2007). Birth year was calculated by subtracting the respondents current age from the year in which the survey was administered. Out of a total possible sample of 1,103,481, I received age information on 1,032,052 respondents (93.53% of the sample).

Split sample design. I employed a split-sample design to mitigate same-source bias. Same-source bias can arise in multi-level studies when the data on group-level variables are derived from the aggregation of individual-level data (Diez Roux 2007). This bias can result in a spurious association between the hypothesized exposures and outcomes because measurement error in both the group-level and the individual-level exposures variables is correlated (because reports of each stem from the same set of individuals).

I aggregated attitudes based on an approximate 1% subset of the total sample using PROC SURVEYSELECT in SAS 9.2; within each year, subsets ranged from 0.8% (1995) to 1.4% (1976). Individuals who provided data on aggregated attitudes did not provide outcome data. In total, 967,562 respondents provide data on alcohol outcomes and 943,644 respondents provide data on cigarette outcomes. I tested whether exposure and outcome derived from the 1% subset differed from the remaining 99%. I tested whether the proportion of individuals who disapproved of alcohol and cigarette use differed between the two samples, and whether the proportion of past-year alcohol and cigarette use different between the two samples. Estimates differed from each other with a mean of 1.2%, and no differences were statistically significant at the $p<0.05$ level. Thus, I concluded the 1% sample used for exposure measurement was a reasonable random sample of the population.

Measures

MTF Questionnaire.

The MTF questionnaire covers a wide range of topic areas, including drug use and related attitudes. Importantly, the measures included in the present study were included at each wave of data collection with no changes to the question wording across years. All respondents were given a “core” questionnaire that assesses the lifetime and current frequency of alcohol and cigarette use.

From 1976 to 1988, 12th grade respondents were randomized to one of five sub-questionnaires. One sub-questionnaire contained questions regarding alcohol and cigarette disapproval. Beginning in 1989, 12th grade respondents were randomized to one of six sub-questionnaires. Depending on year, three or four of these sub-questionnaires contained questions regarding alcohol and cigarette disapproval. Eighth and tenth graders were added to the study design in 1991. All students in 8th and 10th grade were asked about alcohol and cigarette disapproval. Further details of the sampling design and procedures can be found elsewhere (Johnston, O'Malley et al. 2007).

Measures used in the present study.

Outcomes. Respondents answered on how many occasions they consumed alcohol in the past 12 months. Alcohol use measured as a 7-level ordinal variable: 0 occasions, 1-2, 3-5, 6-9, 10-19, 20-39, and 40 or more occasions. Respondents were also queried about frequency of cigarette smoking. Cigarette use measured as a 5-level ordinal variable: never, once or twice, occasionally but not regularly, regularly in the past, and regularly now. Analyses using alternative alcohol and tobacco outcomes are described in **Appendices 4 and 5**.

Individual-level attitudes towards acceptability of using the substance. Respondents were asked: "Individuals differ in whether or not they disapprove of people doing certain things. Do you disapprove of people (who are 18 or older) … Having five or more drinks once or twice each weekend? … Smoking a pack or more of cigarettes a day?" Three response options were allowed: "Don't disapprove", "Disapprove", and "Strongly disapprove".

Socio-demographic characteristics. Previously identified demographic risk factors for alcohol and cigarette use at the individual level were also included in regression models. These included: sex, age, race/ethnicity, and highest level of respondent-identified parental education.

Operationalization of attitudes at the individual and population level

Individual-level social norms. At the individual level, attitudes were operationalized as a three level variable corresponding to the three response options (Don't disapprove, disapprove, and strongly disapprove), with strongly disapprove as the referent group.

Population-level social norms. At the population level, aggregate measures of attitudes towards acceptability of using the substance were created in order to characterize the social norm associated with time periods (year) and birth cohorts. For simplicity, I dichotomized the measures assessing attitudes toward alcohol and cigarette use (strongly disapprove/disapprove vs. don't disapprove). I then determined the proportion of students who disapproved of alcohol and cigarette use in each *time period*. This variable represented the period-specific social norm. For alcohol, these proportions ranged from a low of 55.12 in 1979 to a high of 84.19 in 1992. For tobacco, these proportions ranged from a low of 65.7% in 1976 to a high of 85.74 in 2007. Next, I then determined the proportion of students who disapproved of alcohol and cigarette use in each *birth cohort*. This variable represented the cohort-specific social norm. For alcohol, these proportions ranged from a low of 54.3% for the 1962 cohort to a high of 88.9% for the 1994 cohort. For cigarettes, these proportions ranged from a low of 63.2% for the 1962 cohort to a high of 89.9% for the 1994 cohort. All period- and cohort-specific social norm proportions are shown in **Figures 1** (for alcohol) and **2** (for cigarettes).

Statistical analysis

Sample weighting and treatment of missing data

Sample weights were included to adjust for oversampling of some demographic groups. Clustering by school and primary sampling unit introduce non-independence to this sample; while complex weights to adjust for multi-level clustering are available for each year, these weights cannot be combined across all thirty years. To adjust for sources of non-independence, I followed an approach used in other publications from the MTF data on trends over time by setting our alpha level for Type-I error to 0.01 (O'Malley, Bachman et al. 1984; O'Malley, Bachman et al. 1988; Bachman, Johnston et al. 1998; Johnston, O'Malley et al. 2007).

Analyses were completed using MPLUS version 5.2 (Muthen and Muthen 2009). MPLUS uses full integration maximum-likelihood estimation methods, so that observations with missing data are not excluded from analysis (as would be the case in a traditional list-wise deletion). Rather, only observations with data available on a particular covariate contribute to the estimation of that covariate.

Analytic strategy

Any assessment of age, period, and cohort effects is complicated by the linear relations among the three variables. That is, birth cohort can be fully determined knowing only time period of assessment and age of the respondent (Cohort = Period – Age). This is known as the identification problem (Glenn 2005). Thus, special analytic techniques are required to simultaneously estimate age, period, and cohort effects with substantial limitations due to the strict assumptions required in order to validly infer from obtained estimates.

The incorporation of multi-level modeling to an APC framework may be a useful strategy for overcoming these limitations of traditional APC approaches, and may offer other inferential advantages as well. Recent developments in multi-level modeling for age-period-cohort analyses offer statistical approaches to mitigating the identification problem by specifying a model in which age is an individual-level effect whereas period and cohort are cross-classified random effects (CCREM) (Yang and Land 2006; Yang and Land 2008; Reither, Hauser et al. 2009). For these analyses I followed the general approach outlined by Yang and Land (Yang and Land 2008), whereby age, time period, and birth cohort effects are specified in a CCREM. This method has been applied to diverse outcomes such as obesity (Reither, Hauser et al. 2009) and verbal test scores (Yang and Land 2006). However, this approach has been applied to test for the presence of overall age, period, and cohort effects, rather than mechanisms through which age, period, and cohort effects are generated. I extended the Yang and Land approach by specifying variables on the period and cohort level to explain year- and cohort-specific variation in order to test hypotheses about the mechanisms through which period and cohort effects may emerge (Winship and Harding 2008).

The result was a multi-level model with two levels. Level 1 was the individual level, in which the log odds of a one-unit change in the outcome (frequency of alcohol or cigarette use) were regressed on a set of covariates that included age. Level 2 was the population level, in which the intercept of the individual-level regression from Level 1 was regressed on time period and birth cohort disapproval, considered random effects. The rationale for this individual- and population-level distinction for age versus period and cohort effects was theoretical; I hypothesized that the developmental age of the respondent was associated with alcohol use (and individual-level effect), rather than the age structure of the population (a population-level effect).

Maximum likelihood estimators were used for all models, with the exception of models extracting an r-squared (in those models, weighted least squares estimators were used). For both alcohol and cigarette analyses, I obtained odds ratios and 99% confidence intervals for a one-unit change in the outcome using multinomial logistic regression and specifying an ordered polytomous observed dependent variable. Using a cumulative logit link function for polytomous regression models, a single summary odds ratio was obtained by assuming homogeneity of odds change from one ordered category to another. That is, I assumed that the differences in odds associated with a change from 3-5 drinking occasions to 6-9 drinking occasions was the same as the difference in odds associated with a change from 6-9 drinking occasions to 10-19.

I assessed the relation between disapproval and alcohol/cigarettes use in two ways. First, I examined the log odds associated with a 5% increase in the population-level disapproval variables, thus treating population-level disapproval as a continuous variable. This model assumes that the difference in odds is equal at any point along the continuum of disapproval. Preliminary descriptive analyses suggested that this assumption was appropriate. However, I also divided population-level disapproval into a categorical variable to examine the log odds associated with each category of population-level disapproval, in order to detect any non-linear effects. Both analyses are presented here. I first assessed the effects of period-specific social norms and cohort-specific social norms in separate models controlled only for individual-level age. I then assessed the effects of period-specific social norms and cohort-specific social norms simultaneously in a model controlled for individual-level covariates of age, race, sex, highest level of parental education and personal attitude toward disapproval.

Multiple-group analysis.

Finally, I determined if the structure of the CCREMs differed by socio-demographic characteristics. For this, I used multiple group analysis, which tests for measurement invariance of the functional form of the model across groups. I calculated a coefficient for the difference between groups by using a two-level mixture model using the KNOWNCLASS option of MPLUS version 5.12 mixture models; if the coefficient was not significantly different from zero, I concluded that models are structurally invariant, as described in detail elsewhere (Millsap and Yun-Tein 2004). Given the large sample size of the MTF, I also assessed the strength of the difference in odds ratios by demographic characteristics; only changes that were greater than 10% were considered meaningful. This decision rule was based on common practice in epidemiology of judging appreciable changes in effect estimates to be greater than ten percent (Aschengrau and Seage 2008). I tested for measurement invariance for females versus males, whites versus non-whites, and parental education (less than high school and greater than high school both compared to high school as the reference group).

Results

Alcohol use by age, period, and cohort

The mean alcohol use frequency by age, period, and cohort are shown in **Figure 3.1**. By age, mean number of alcohol using occasions increases and disapproval decreases until approximately age 17, after which both measures remain stable. By period, binge drinking was highest (4.4, indicating between 6-9 and 10-16 drinking occasions in the past year) and disapproval lowest (67.4%) in 1981; in contrast, use was lowest in 1996 (1.84, indicating a mean of around 3-5 drinking occasions in the past year) and disapproval highest in 1992 (83.3%). By cohort, mean number of alcohol using occasions was highest (4.5, indicating between 6-9 and 10-16 drinking occasions in the past year) and disapproval lowest (66.9%) for

the cohort born in 1962; in contrast, mean number of drinking occasions was lowest (1.2, indicating between 1-2 and 3-5 drinking occasions in the past year) and disapproval highest (84.3%) for the cohort born in 1994.

Cigarette use by age, period, and cohort

The prevalence of past 30-day cigarette use and disapproval or strong disapproval of pack-a-day smoking by age, period, and cohort is shown in **Figure 3.2**. By age, smoking consistently increases and disapproval decreases from 13 to 19. By period, smoking was highest (38.8%) and disapproval lowest (65.7%) in the earliest year collected (1976); use was lowest (14.0%) and disapproval highest (85.7%) in the latest year collected (2007). By cohort, smoking was highest among the cohort born in 1959 (38.4%) and disapproval lowest among the cohort born in 1957 (63.2%); in contrast, smoking was lowest (4.3%) and disapproval highest (92.4%) for the cohort born in 1994.

Cross-classified random effects models (CCREM): alcohol

First, I evaluated the effect of cohort- and period-specific disapproval on alcohol use occasions when disapproval was defined as a continuous predictor (see **Table 3.1**). For period, each five percentage point increase in disapproval there was a 0.71 times decrease in alcohol using occasions in an model adjusted only for age (OR=0.71, 99% C.I. 0.70-0.72, $p<0.01$). For cohort, each five percentage point increase in cohort-specific disapproval was associated with a 0.75 times decrease in alcohol using occasions in a model adjusted only for age (OR=0.75, 99% C.I. 0.72-0.78, $p<0.01$). Cohort-specific disapproval remained significantly associated with number of alcohol using occasions (OR=0.88, 95% C.I. 0.87-0.89) whereas period-specific disapproval did not in a regression model simultaneously controlled for period and cohort-specific disapproval as well as individual-level disapproval and demographics,. The final model explained 80% of the between-level variance in the multi-level model, and 36% of the within level variance. Analyses using alternative outcome measures of alcohol use are described in **Appendix 4**.

Second, I evaluated the effect of cohort- and period-specific disapproval on alcohol use occasions when disapproval was defined as a categorical predictor. Results are shown in **Figure 3.3**. For period, no consistent or theorized pattern emerges for the relation between period-specific disapproval and alcohol use in controlled regression. For cohort, a stepwise decrease in the odds of alcohol use occurs as the birth cohort-specific disapproval increases, until a threshold effect of approximately 75% of the birth cohort disapproving. Cohort-specific odds ratios correspond closely to the shape of the distribution of mean alcohol use across cohort-specific disapproval categories. Analyses are controlled for individual-level disapproval and demographics.

Multiple group analysis

Finally, I conducted multiple group analyses to determine whether the structure of the model differed by sex, race, and highest level of parental education. All multiple group analyses were statistically significant ($p<0.01$). I then examined the odds ratios for the association between cohort-specific disapproval and alcohol use within demographic subgroups; the odds ratio for men versus women differed by 6%, and the odds ratios comparing parental educational levels differed by less than 5%; this suggests little evidence of an appreciable difference. The odds ratios for non-Whites compared to Whites, however, differed by 16%. Given the magnitude of this difference, odds ratios for the effect of cohort-specific disapproval on alcohol use subset by

race are shown in **Figure 3.4**. The effect of disapproval on use was stronger among white adolescents, especially those living in birth cohorts where more than 78% or more of adolescents disapproved of frequent binge drinking (see Figure 4). Among white adolescents, the odds of alcohol consumption occasions decreased by approximately 30% for each five percentage point increase in disapproval (OR=0.73, 95% C.I. 0.64-0.83). Among non-white adolescents, the odds of alcohol consumption occasions decreased by approximately 13% of each five percentage point increase in disapproval (OR=0.87, 95% C.I. 0.85-0.89).

Cross-classified random effects models (CCREM): cigarettes

Similar to the above, first I evaluated the effect of cohort- and period-specific disapproval on cigarette use when disapproval was defined as a continuous predictor (see **Table 3.2**). For period, a five percentage point increase in period-specific disapproval was associated with a decrease in cigarette use in unadjusted models (OR=0.85, 99% C.I. 0.74-0.98, $p<0.01$). That is, each five percentage point increase in disapproval was associated with a 0.85 times decreased odds of escalating cigarette use (e.g., going from past occasional smoking to past regular smoking, or from past regular smoking to current regular smoking). For cohort, each five percentage point increase in cohort-specific disapproval was associated with a decrease in escalating cigarette use in an unadjusted model (OR=0.86, 99% C.I. 0.85-0.87, $p<0.01$). Period-specific disapproval remained significantly associated with cigarette consumption (OR=0.61, 95% C.I. 0.89-0.92) whereas cohort-specific disapproval did not in a regression model simultaneously controlled for period and cohort-specific disapproval as well as individual-level disapproval and demographics. The final model explained 60% of the between-level variance in the multi-level model, and 29% of the within level variance. Analyses using alternative outcome measures of alcohol use are described in **Appendix 5**.

Second, I evaluated the effect of cohort- and period-specific disapproval on cigarette use when disapproval was defined as a categorical predictor. Results are shown in **Figure 3.5**. For period, there is a stepwise decrease in the odds of cigarette use as the period-specific disapproval increases; compared to years in which 65-69% of adolescents disapproved of cigarette use, odds of cigarette use significantly decreased in years where 80-84% of adolescents disapproved (OR=0.76, 99% C.I. 0.59, 0.99) and in years where 85-89% of adolescents disapproved (OR=0.67, 99% C.I. 0.50, 0.89). For cohort, no level of cohort disapproval significantly predicted cigarette use in controlled models.

Multiple group analysis

Finally, I conducted multiple group analyses to determine whether the structure of the model differed by sex, race, and highest level of parental education. All multiple group analyses were statistically significant ($p<0.01$). I then examined the odds ratios for the association between period- and cohort-specific disapproval and alcohol use within demographic subgroups; all odds ratios differed by less than 5%, suggesting little evidence of an appreciable difference.

Discussion

The present study resulted in three main findings. First, I document social norm-mediated cohort effects in adolescent alcohol use, whereby members of birth cohorts with increased disapproval of alcohol use have fewer alcohol using occasions, controlling for individual-level attitudes toward alcohol. Second, I do not find social norm-mediated cohort effects in adolescent cigarette use. Instead, I document social norm-mediated period effects, whereby adolescents measured in years of higher disapproval are less likely to use cigarettes, controlling for

individual-level attitudes toward cigarettes. Age effects are present for both alcohol and cigarette use, with use more frequent at older ages. Third, for alcohol use, I document significant variation in cohort-specific disapproval effects across race, i.e., the effect of population-level disapproval on alcohol use is stronger among White adolescents than non-White adolescents. This study represents a potential model for future investigations of age-period-cohort effects. Rather than engaging in analyses that partition variance into components of age, period, and cohort, the present study directly tests specific hypotheses about a mechanism that may give rise to such effects over time.

The differences in results for alcohol versus tobacco raise interesting questions about the heterogeneous processes govern ways that social norms towards substance use. For cigarettes, the association between period-specific disapproval and use may be explained by widespread changes in social norms, policies, and laws that have impacted all age groups simultaneously. U.S. cigarette use has exhibited substantial declines across age groups since the beginning of the Monitoring the Future study, concurrently with numerous efforts to reduce smoking at the aggregate level, including extensive public health campaigns (Levy, Chaloupka et al. 2004; Farrelly, Davis et al. 2005; Farrelly, Nonnemaker et al. 2009), policies prohibiting smoking in indoor spaces (Farrelly, Evans et al. 1999; Bitton, Fichtenberg et al. 2001; Fichtenberg and Glantz 2002) laws prohibiting television advertising, and increased taxes on cigarette purchases (Baltagi and Levin 1986; Chaloupka 1991; Yen and Jones 1996). Epidemiologic evidence supports the efficacy of these measures to both reduce cigarette consumption and increase perception of social unacceptability across age groups (Gilpin, Lee et al. 2004; Alamar and Glantz 2006), suggesting that the period effects found here may be mediated through broader public health and legal pathways. In contrast, alcohol policies and laws have focused on certain age groups, potentially giving rise to a cohort-specific relation between disapproval and alcohol use found in these data. Most notably, the change in the legal drinking age from 18 to 21, which varied by state until 1988, may have been operative in the shift in drinking patterns and/or social norms regarding drinking. Policies that affect some age groups more than others would produce cohort effects rather than period effects. The preponderance of evidence (reviewed in (Wagenaar and Toomey 2002)) indicates that increases in the minimum drinking age reduce alcohol consumption, traffic fatalities and crashes, and alcohol problems among adolescents. In contrast, changes in minimum drinking age laws do not have strong effects on adult drinking (Wagenaar and Toomey 2002). Thus, the consumption patterns and social norms regarding alcohol use of each birth cohort may be impacted by the drinking age laws operative during the birth cohort's adolescence. Further, studies have documented overall increases in the unacceptability of alcohol-related behaviors such as public drunkenness and driving after drinking (Greenfield and Room 1997). If these attitudes toward alcohol consumption vary according to birth cohort, then social norm-mediated cohort effects in alcohol consumption may arise.

Taken together, these data suggest interesting avenues for further hypothesis testing about the differential role of policy, law, and other macro-environmental changes in shifting social norms, and subsequently alcohol and cigarette use in the population. Previous work in these data by Bachman et al. (Bachman, Johnston et al. 1998) indicated that perceived risks and disapproval explained increases in marijuana use throughout the 1980's and 1990's. The present investigation further that line of inquiry by partitioning the contribution of social norms by age, period, and cohort, documenting unique and differential effects by substance. Future investigations with more micro-geographical data would be useful to tease apart the relations between policy/law and social norms; for example, comparing changes in social norms and in the prevalence of substance use in two states over time, one of which experienced a policy

change. Longitudinal data with comprehensive geographical information would be useful for these future investigations.

I found that cohort-specific and period-specific disapproval is associated with alcohol and cigarette use, respectively, controlling for personal attitude toward alcohol and cigarette use. Pathways through which social norms affect substance use that are unmediated by their effect on personal attitudes have been theorized according to the contagion model (Wilcox 2003). These models suggest that norms may be 'transmitted' to individuals in the same time (period effects) or cohort (cohort effects) and that this transmission of norms may be affect behavior through the passive acquisition of the norm rather than direct confirmation (Bandura, Ross et al. 1961; Bandura 1977; Bandura 2001). Support for the contagion model in substance use can be found in the vast literature describing the strong effect of peer association and peer group descriptive and injunctive norms on substance use (Hill 1971; Kandel 1985; Brook, Nomura et al. 1989; Biglan, Duncan et al. 1995; Beal, Ausiello et al. 2001; Kuntsche and Jordan 2006). However, individuals self-select into peer groups in ways that may be related to substance use, suggested a more complicated etiologic pathway. There is evidence that socially normative cues affect behavior without direct perception form individuals. For example, a recent randomized study in the Netherlands found that individuals were more likely to litter and steal when investigators placed graffiti and litter in the immediate environment (Keizer, Lindenberg et al. 2008). Further development of contagion models through complex systems and generative models (Kaplan 2004; Ahern, Jones et al. 2008; Auchincloss and Diez Roux 2008; Galea, Hall et al. 2009) that allow non-independent outcomes may be helpful as a future research area to test hypotheses about the processes through which norms and behavior are transmitted over time and within cohorts.

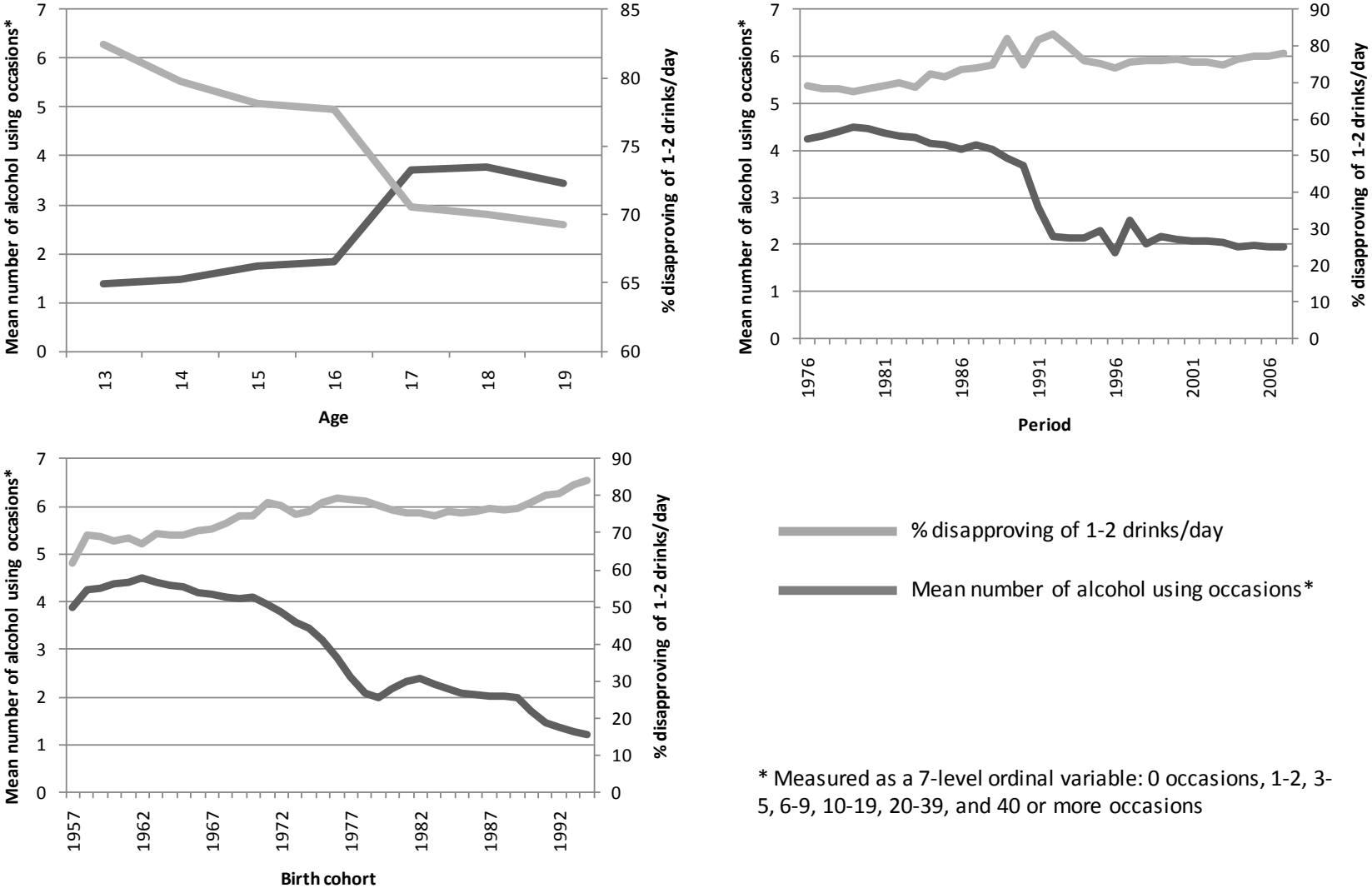
Finally, I document that the effects of cohort-specific social norms on alcohol use vary according to socio-demographic characteristics, most notably that the effect of disapproval on alcohol use is stronger for Whites than for non-Whites. Studies have consistently documented that overall, Black adolescents report higher disapproval of alcohol use and consume less alcohol, compared to White adolescents (Forney, Forney et al. 1988; Gillmore, Wells et al. 1998; Ellickson, Collins et al. 1999; Ellickson and Morton 1999; Rinehart, Bridges et al. 2006). Thus, the effects of disapproval may be less salient for Blacks than Whites, due to the overall higher mean disapproval and lower overall mean use. This hypothesis is supported by previous research on adolescents suggesting that perceptions of norms regarding marijuana use had a greater effect on subsequent use in White adolescents compared to Black adolescents (Ellickson and Morton 1999).

Limitations of the study are noted. From 1976 to 1990, only 12th grade respondents were surveyed (ages ranging from 17-19). Thus, limited age and cohort variation during this period reduce the ability to separate period from cohort effects. I was concerned about bias introduced into the estimates, as social norms vary by age (thus differences in ages across years should give rise to differences in the population-level prevalence of disapproval). However, I theorized that while there will be absolute differences in the population-level prevalence across age, evidence for bias would only be present if the relation between disapproval and use varied as a function of age. I conducted several sensitivity analyses to assess the impact of differential age availabilities across years. First, I stratified each multi-level regression by age to examine evidence for variation in the magnitude of the effects across age. I found little evidence for systematic variation in the relation between disapproval and use by age (see Appendix 7). This indicates that, while the absolute prevalence of disapproval is impacted by measurement, the effect estimates described in our results are not. Second, I stratified each multi-level regression by year of observation, with one strata indicating observation from 1976 through 1990 when

only 12th grade respondents were included, and one strata indicating observation from 1991 forward when 8th, 10th, and 12th grade respondents were included. The direction and magnitude of the effect estimates were similar in these subsets (see **Appendix 7**), indicating little evidence for bias. As in all large-scale research of substance use, information is based on self-report rather than biological markers; some misclassification of alcohol and cigarette use is inevitable. However, the validity of self-report was maximized by the use of sealed, personal questionnaires rather than face to face interviewing. Finally, because MTF is a school-based survey, high school drop-outs are not included in any survey estimates. This is a minor issue for the eighth grade survey; however, by tenth grade approximately 5% of adolescents drop-out, and by twelfth grade between 15 to 20% of each cohort is missing due to drop out (Johnston, O'Malley et al. 2007). The conclusions from this study can be generalized only to high-school attending students, which represent the large majority of adolescents in the United States.

In conclusion, the present research adds to the accumulating body of evidence suggesting that social norms, conceptualized at multiple levels, are important determinants of adolescent alcohol and cigarette use (Brook, Nomura et al. 1989; Ennett, Flewelling et al. 1997; Rountree and Clayton 1999; Ahern, Galea et al. 2008; Ahern, Galea et al. 2009). I document specificity in the effect of social norms defined across time; the disapproval within an individual's birth cohort may be a salient risk factor for alcohol use, whereas the disapproval associated with a certain time period may be a salient risk factor for cigarette use. Future studies incorporating a wide range of group-level norms, patterns of use, and individual-level attitudes would be helpful to extend the current research and determine the specific attitudes and behaviors that shape patterns of alcohol and cigarette use at the individual level. Finally, the incorporation of multi-level modeling to an APC framework may be a useful strategy for overcoming these limitations of traditional APC approaches, allowing for tests of specific hypotheses through which age, period, and cohort effects arise. As theory continues to develop regarding the complex processes through which social norms across time impact individual behavior, strong hypothesis testing regarding these mechanisms will continue to advance the research agenda focusing on the prevention of adolescent substance use.

Figure 3.1. Age, period, and cohort association with percentage of high school students in the U.S. disapproving or strongly disapproving of 1-2 drinks/day alcohol consumption and mean number of drinking occasions* in the past year, 1976-2007 (N=967,562)



* Measured as a 7-level ordinal variable: 0 occasions, 1-2, 3-5, 6-9, 10-19, 20-39, and 40 or more occasions

Figure 3.2. Age, period, and cohort association with percentage of high school students in the U.S. disapproving or strongly disapproving of pack-a-day smoking and percentage of students reporting any past 30-day cigarette use, 1976-2007 (N=943,644)

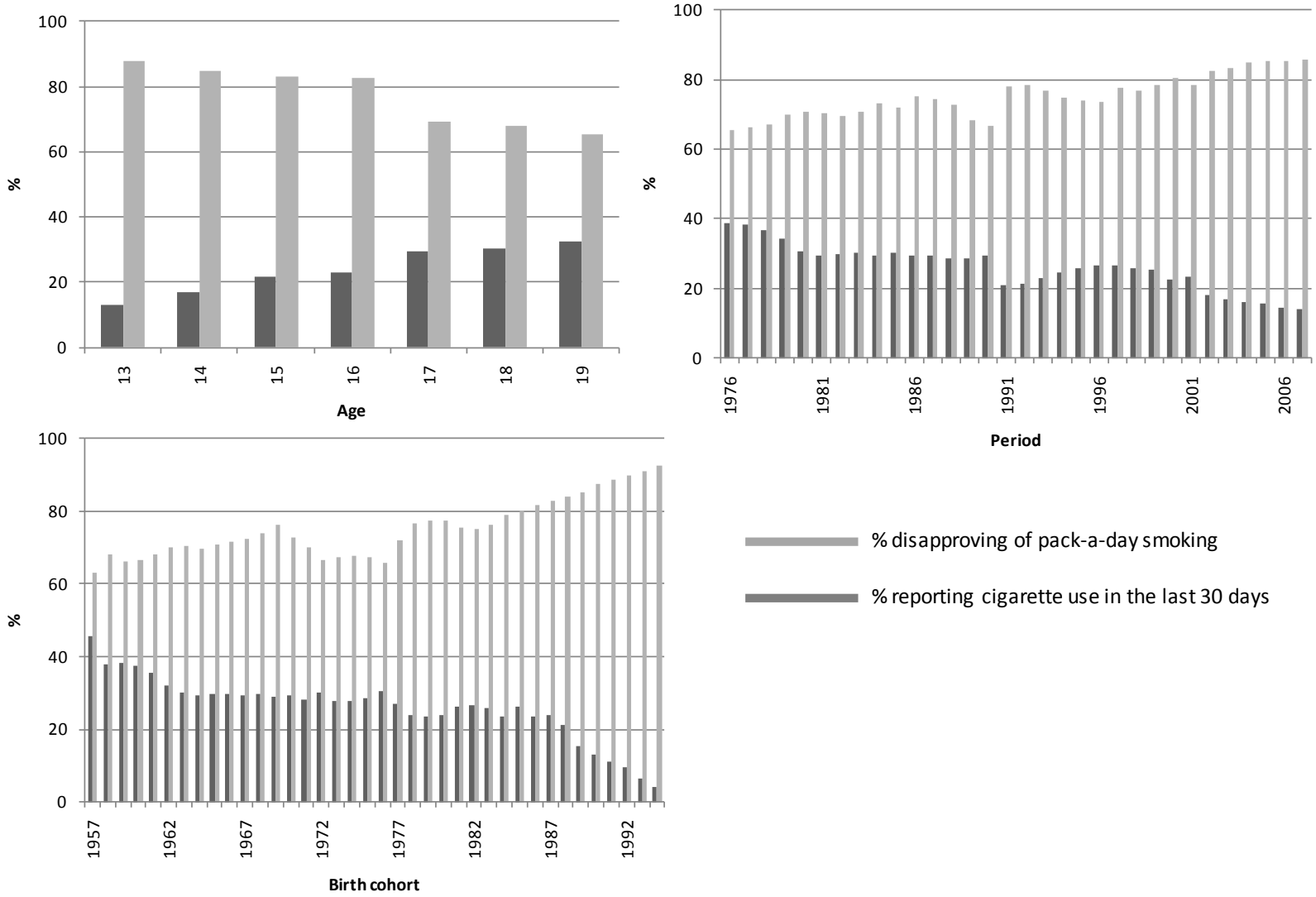


Table 3.1. Effect of population-level disapproval on frequency of alcohol consumption[+] in the past 12-months among high school students in the U.S. from 1976-2007[+] (N=967,562)

	Frequency of alcohol consumption in the past 12-months					
	Model 1*		**Model 2***		**Model 3****	
	Odds ratio (99% C.I.)	**p-value**	**Odds ratio (99% C.I.)**	**p-value**	**Odds ratio (99% C.I.)**	**p-value**
Period-specific disapproval	0.71 (0.70-0.72)	<0.01			0.96 (0.92-1.01)	0.65
Cohort-specific disapproval			0.75 (0.72-0.78)	<0.01	0.88 (0.87-0.89)	0.004
Log-likelihood	-1,794,972.499		-1,796,988.765		-830,897.653	
R-squared (within)	0.150	<0.01	0.125	<0.01	0.360	<0.01
R-squared (between)	0.861	<0.01	0.834	<0.01	0.798	<0.01

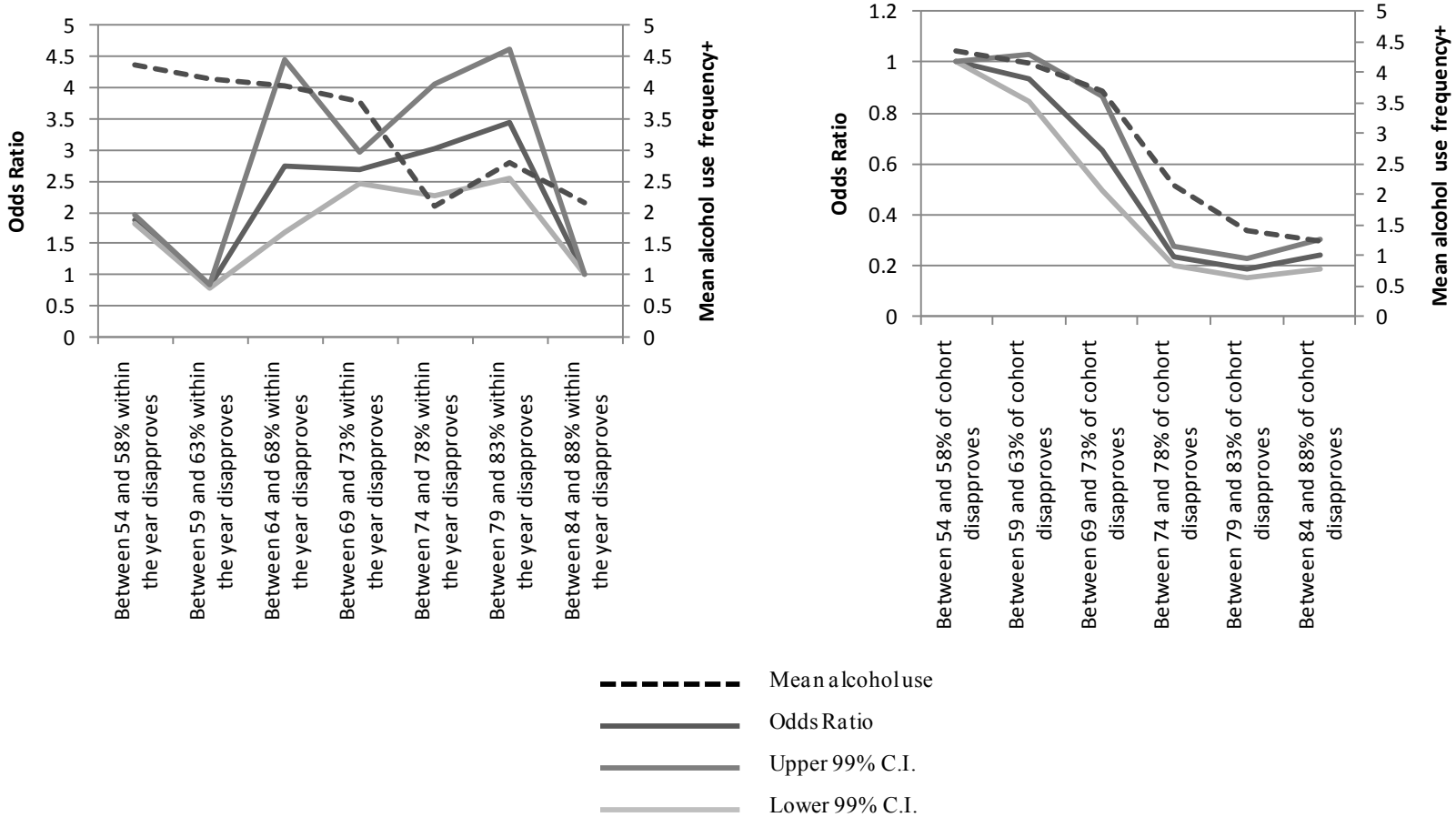
[+] Models estimated as cross-classified random effects models with period-specific and cohort-specific disapproval as random effects and age as an individual-level effect.

*Controlled for individual-level age

** Controlled for year- and cohort-specific disapproval, individual-level age, individual-level disapproval, sex, race, and highest level of parental education

[+] Alcohol use measured as a 7-level ordinal variable: 0 occasions, 1-2, 3-5, 6-9, 10-19, 20-39, and 40 or more occasions

Figure 3.3. Mean alcohol use frequency[+] and summary odds ratio* for the effect of cohort-specific and period-specific disapproval on frequency of alcohol consumption in the past 12-months among high school students in the U.S. from 1976-2007 (N=967,562)



* Odds ratio from multi-level polytomous regression with a cumulative logit link function models including year- and cohort-specific disapproval, individual-level disapproval, age, sex, race, and highest level of parental education. Odds ratio interpreted as the change in odds of increasing alcohol use frequency based on a five percentage point change in disapproval at the period (left) or cohort (right) level.

[+] Alcohol use measured as a 7-level ordinal variable: 0 occasions, 1-2, 3-5, 6-9, 10-19, 20-39, and 40 or more occasions

Figure 3.4. Association between cohort-specific disapproval of frequent binge drinking and frequency of alcohol use, among White adolescents (N=698,413) **and non-White adolescents** (N=150,270) **in the United States, 1976-2007**

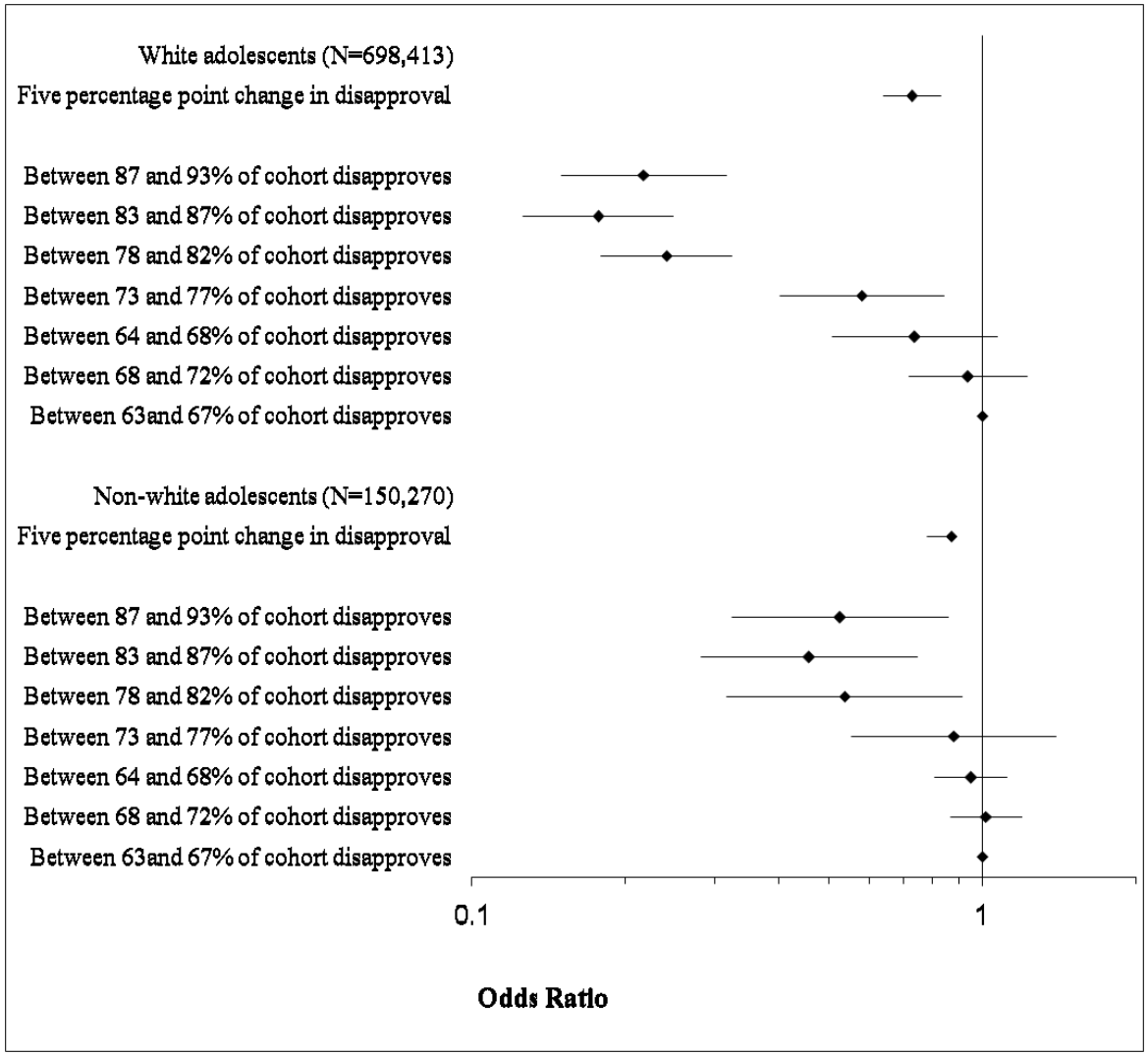


Table 3.2. Effect of population-level disapproval on frequency of lifetime cigarette use patterns[+] among high school students in the U.S. from 1976-2007 (N=967,562)

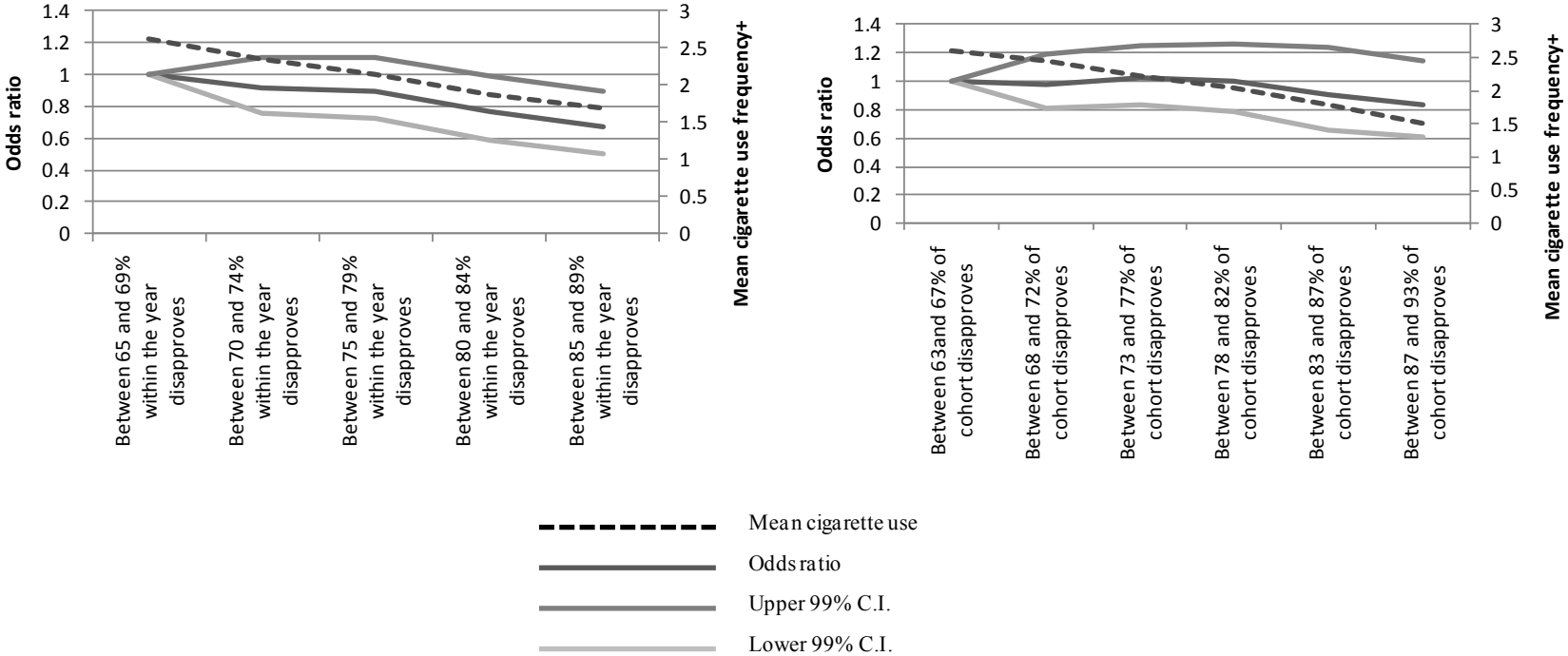
	Frequency of lifetime cigarette use patterns					
	Model 1*		**Model 2***		**Model 3****	
	Odds ratio (99% C.I.)	**p-value**	**Odds ratio (99% C.I.)**	**p-value**	**Odds ratio (99% C.I.)**	**p-value**
Year-specific disapproval	0.85 (0.74-0.98)	<0.01	--		0.81 (0.79-0.82)	<0.01
Cohort-specific disapproval	--		0.86 (0.85-0.87)	<0.01	1.00 (0.98-1.01)	0.91
Log-likelihood	-1,499,577.07		-1,501,115.55		-672,515.15	
R-squared (within)	0.037	<0.01	0.023	<0.01	0.285	<0.01
R-squared (between)	0.724	<0.01	0.788	<0.01	0.596	<0.01

*Controlled for individual-level age

** Controlled for year- and cohort-specific disapproval, individual-level age, individual-level disapproval, sex, race, and highest level of parental education

[+] Cigarette use measured as a 5-level ordinal variable: never, once or twice, occasionally but not regularly, regularly in the past, and regularly now.

Figure 3.5. Mean cigarette use frequency[+] and summary odds ratio for the effect of cohort-specific and period-specific disapproval on lifetime cigarette use patterns among high school students in the U.S. from 1976-2007 (N=943,644)



* Odds ratio from multi-level polytomous regression with a cumulative logit link function models including year- and cohort-specific disapproval, individual-level disapproval, age, sex, race, and highest level of parental education. Odds ratio interpreted as the change in odds of increasing cigarette use frequency based on a five percentage point change in disapproval at the period (left) or cohort (right) level.

[+] Cigarette use measured as a 5-level ordinal variable: never, once or twice, occasionally but not regularly, regularly in the past, and regularly now.

References

Ahern, J., S. Galea, et al. (2008). ""Culture of drinking" and individual problems with alcohol use." Am J Epidemiol **167**(9): 1041-9.

Ahern, J., S. Galea, et al. (2009). "Neighborhood smoking norms modify the relation between collective efficacy and smoking behavior." Drug Alcohol Depend **100**(1-2): 138-45.

Ahern, J., M. R. Jones, et al. (2008). "Revisiting rose: comparing the benefits and costs of population-wide and targeted interventions." Milbank Q **86**(4): 581-600.

Ajzen, I. (1991). "The Theory of Planned Behavior." Organizational Behavior and Human Decision Processes **50**: 179-211.

Alamar, B. and S. A. Glantz (2006). "Effect of increased social unacceptability of cigarette smoking on reduction in cigarette consumption." Am J Public Health **96**(8): 1359-63.

Anthony, J. C., L. A. Warner, et al. (1994). "Comparative Epidemiology of Dependence on Tobacco, Alcohol, Controlled Substances, and Inhalants: Basic Findings From the National Comorbidity Survey." Experimental and Clinical Psychopharmacology **2**(3): 244-268.

Aschengrau, A. and G. R. Seage (2008). Essentials of Epidemiology in Public Health, 2nd edition. Sudbury, MA, Jones and Bartlett Publishers.

Auchincloss, A. H. and A. V. Diez Roux (2008). "A new tool for epidemiology: the usefulness of dynamic-agent models in understanding place effects on health." Am J Epidemiol **168**(1): 1-8.

Bachman, J. G., L. D. Johnston, et al. (1998). "Explaining recent increases in students' marijuana use: impacts of perceived risks and disapproval, 1976 through 1996." Am J Public Health **88**(6): 887-92.

Baltagi, B. H. and D. Levin (1986). "Estimating dynamic demand for cigarettes using panel data: the effects of bootleggint, taxation, and advertising reconsidered." Rev Economics Stat **68**: 148-155.

Bandura, A. (1977). Social Learning Theory, Prentice Hall.

Bandura, A. (2001). "Social cognitive theory: an agentic perspective." Annu Rev Clin Psychol **52**: 1-26.

Bandura, A., D. Ross, et al. (1961). "Transmission of agressions through imitation of agressive models." Journal of Abnormal and Social Psychology **63**: 575-582.

Baranowski, T., C. L. Perry, et al. (1997). How individuals, environments, and health behaviors interact: Social Cognitive Theory. Health Behavior and Health Education: Theory, Research, and Practive. K. Glanz, F. M. Lewis and B. K. Rimer. San Francisco, Jossey-Bass Inc.

Beal, A. C., J. Ausiello, et al. (2001). "Social influences on health-risk behaviors among minority middle school students." J Adolesc Health **28**(6): 474-80.

Biglan, A., T. E. Duncan, et al. (1995). "Peer and parental influences on adolescent tobacco use." J Behav Med **18**(4): 315-30.

Bitton, A., C. Fichtenberg, et al. (2001). "msJAMA: reducing smoking prevalence to 10% in five years." JAMA **286**(21): 2733-4.

Blount, W. R. and R. Dembo (1984). "The effect of perceived neighborhood setting on self-reported tobacco, alcohol, and marijuana use among inner-city minority junior high school youth." Int J Addict **19**(2): 175-98.

Brook, J. S., C. Nomura, et al. (1989). "A network of influences on adolescent drug involvement: neighborhood, school, peer, and family." Genet Soc Gen Psychol Monogr **115**(1): 123-45.

Chaloupka, F. (1991). "Rational addictive behavior and cigarette smoking." J Political Economy **99**: 722-742.

Chassin, L., C. C. Presson, et al. (2007). "Deviance proneness and adolescent smoking 1980 vs. 2001: Has there been a hardening of adolescent smoking?" Journal of Applied Developmental Psychology **28**: 264-276.

Chen, X., G. Li, et al. (2003). "Secular trends in adolescent never smoking from 1990 to 1999 in California: an age-period-cohort analysis." Am J Public Health **93**(12): 2099-104.

Chuang, Y. C., C. Cubbin, et al. (2005). "Effects of neighbourhood socioeconomic status and convenience store concentration on individual level smoking." J Epidemiol Community Health **59**(7): 568-73.

Chuang, Y. C., S. T. Ennett, et al. (2005). "Neighborhood influences on adolescent cigarette and alcohol use: mediating effects through parent and peer behaviors." J Health Soc Behav **46**(2): 187-204.

Chuang, Y. C., Y. S. Li, et al. (2007). "A multilevel analysis of neighborhood and individual effects on individual smoking and drinking in Taiwan." BMC Public Health **7**: 151.

Crum, R. M., M. Lillie-Blanton, et al. (1996). "Neighborhood environment and opportunity to use cocaine and other drugs in late childhood and early adolescence." Drug Alcohol Depend **43**(3): 155-61.

Datta, G. D., S. V. Subramanian, et al. (2006). "Individual, neighborhood, and state-level predictors of smoking among US Black women: a multilevel analysis." Soc Sci Med **63**(4): 1034-44.

Degenhardt, L., W. T. Chiu, et al. (2007). "Epidemiological patterns of extra-medical drug use in the United States: evidence from the National Comorbidity Survey Replication, 2001-2003." Drug Alcohol Depend **90**(2-3): 210-23.

Dembo, R., W. R. Blount, et al. (1986). "Perceived environmental drug use risk and the correlates of early drug use or nonuse among inner-city youths: the motivated actor." Int J Addict **21**(9-10): 977-1000.

Diez Roux, A. V. (2007). "Neighborhoods and health: where are we and were do we go from here?" Rev Epidemiol Sante Publique **55**(1): 13-21.

Duncan, C., K. Jones, et al. (1999). "Smoking and deprivation: are there neighbourhood effects?" Soc Sci Med **48**(4): 497-505.

Eilstein, D., Z. Uhry, et al. (2008). "Lung cancer mortality in France. Trend analysis and projection between 1975 and 2012, using a Bayesian age-period-cohort model." Lung Cancer **59**(3): 282-90.

Eisenberg, M. E. and J. L. Forster (2003). "Adolescent smoking behavior: measures of social norms." Am J Prev Med **25**(2): 122-8.

Ellickson, P. L., R. L. Collins, et al. (1999). "Adolescent use of illicit drugs other than marijuana: how important is social bonding and for which ethnic groups?" Subst Use Misuse **34**(3): 317-46.

Ellickson, P. L. and S. C. Morton (1999). "Identifying adolescents at risk for hard drug use: racial/ethnic variations." J Adolesc Health **25**(6): 382-95.

Ennett, S. T., R. L. Flewelling, et al. (1997). "School and neighborhood characteristics associated with school rates of alcohol, cigarette, and marijuana use." J Health Soc Behav **38**(1): 55-71.

Fagan, P., M. Eisenberg, et al. (2001). "Social influences, social norms, social support, and smoking behavior among adolescent workers." Am J Health Promot **15**(6): 414-21.

Farrelly, M. C., K. C. Davis, et al. (2005). "Evidence of a dose-response relationship between "truth" antismoking ads and youth smoking prevalence." Am J Public Health **95**(3): 425-31.

Farrelly, M. C., W. N. Evans, et al. (1999). "The impact of workplace smoking bans: results from a national survey." Tob Control **8**(3): 272-7.

Farrelly, M. C., J. Nonnemaker, et al. (2009). "The Influence of the National truth campaign on smoking initiation." Am J Prev Med **36**(5): 379-84.

Feighery, E., D. G. Altman, et al. (1991). "The effects of combining education and enforcement to reduce tobacco sales to minors. A study of four northern California communities." JAMA **266**(22): 3168-71.

Fichtenberg, C. M. and S. A. Glantz (2002). "Effect of smoke-free workplaces on smoking behaviour: systematic review." BMJ **325**(7357): 188.

Fishbein, M. and I. Ajzen (1975). Beliefs, attitude, intention, and behavior. Reading, MA, Addison Wesley.

Forney, P. D., M. A. Forney, et al. (1988). "Alcohol and adolescents. Knowledge, attitudes, and behavior." J Adolesc Health Care **9**(3): 194-202.

French, K., A. M. Porter, et al. (1982). "Attendance at a breast screening clinic: a problem of administration or attitudes." Br Med J (Clin Res Ed) **285**(6342): 617-20.

Galea, S., C. Hall, et al. (2009). "Social epidemiology and complex system dynamic modelling as applied to health behaviour and drug use research." Int J Drug Policy **20**(3): 209-16.

Galea, S., A. Nandi, et al. (2004). "The social epidemiology of substance use." Epidemiol Rev **26**: 36-52.

Gillmore, M. R., E. A. Wells, et al. (1998). "Children's beliefs about drinking." Am J Drug Alcohol Abuse **24**(1): 131-51.

Gilpin, E. A., L. Lee, et al. (2004). "Changes in population attitudes about where smoking should not be allowed: California versus the rest of the USA." Tob Control **13**(1): 38-44.

Glenn, N. D. (2005). Cohort analysis, second edition. Thousand Oaks, CA, Sage Publications Inc.

Greenfield, T. K. and R. Room (1997). "Situational norms for drinking and drunkenness: trends in the US adult population, 1979-1990." Addiction **92**(1): 33-47.

Henderson, C., X. Liu, et al. (2004). "The effects of US state income inequality and alcohol policies on symptoms of depression and alcohol dependence." Soc Sci Med **58**(3): 565-75.

Hill, D. (1971). "Peer Group Conformity in Adolescent Smoking and Its Relationship to Affiliation and Autonomy Needs." Australian Journal of Psychology **23**: 189-199.

Johnston, L. (1973). Drugs and American Youth. Ann Arbor, MI, Institute for Social Research.

Johnston, L., P. M. O'Malley, et al. (2007). "Monitoring the Future national survey results on drug use, 1975-2006: Volume I, Secondary school students." Bethesda, MD: National Institute on Drug Abuse.

Johnston, L. D., P. M. O'Malley, et al. (2007). Monitoring the Future national survey results on drug use, 1975-2006: Volume I, Secondary school students. Bethesda, MD, National Institute on Drug Abuse.

Kandel, D. B. (1985). On Process of Peer Influences in Adolescent Drug Use: A Developmental Perspective. Alcohol and substance abuse in adolescence. D. W. Brook and D. J. Lettieri, Routledge.

Kaplan, G. A. (2004). "What's wrong with social epidemiology, and how can we make it better?" Epidemiol Rev **26**: 124-35.

Karvonen, S. and A. H. Rimpela (1997). "Urban small area variation in adolescents' health behaviour." Soc Sci Med **45**(7): 1089-98.

Keizer, K., S. Lindenberg, et al. (2008). "The spreading of disorder." Science **322**(5908): 1681-5.

Keyes, K. M., G. Li, et al. (under review). "Birth cohort effects and gender differences in alcohol epidemiology: a review and synthesis." Addiction.

Kleinschmidt, I., M. Hills, et al. (1995). "Smoking behaviour can be predicted by neighbourhood deprivation measures." J Epidemiol Community Health **49 Suppl 2**: S72-7.

Komro, K. A., M. C. McCarty, et al. (2003). "Parental, family, and home characteristics associated with cigarette smoking among adolescents." Am J Health Promot **17**(5): 291-9.

Kuntsche, E. and M. D. Jordan (2006). "Adolescent alcohol and cannabis use in relation to peer and school factors. Results of multilevel analyses." Drug Alcohol Depend **84**(2): 167-74.

Levy, D. T., F. Chaloupka, et al. (2004). "The effects of tobacco control policies on smoking rates: a tobacco control scorecard." J Public Health Manag Pract **10**(4): 338-53.

Mannheim, K. (1952). The Problem of Generations. The Problem of Generations. P. Kecskemeti. London, Routledge and Kegan Paul**:** 276-320.

Millsap, R. E. and J. Yun-Tein (2004). "Assessing factorial invariance in ordered-categorical measures." Multivariate Behavioral Research **39**(479-515).

Monitoring the Future "http://monitoringthefuture.org/."

Muthen, L. K. and B. O. Muthen (2009). "Mplus user's guide (5th Ed)." Los Angeles, CA.

Nurco, D. N., T. Kinlock, et al. (1996). "Perceptions of social pathology in the neighborhood and the etiology of narcotic addiction. A retrospective study." J Nerv Ment Dis **184**(1): 35-42.

O'Malley, P. M., J. G. Bachman, et al. (1984). "Period, age, and cohort effects on substance use among American youth, 1976-82." Am J Public Health **74**(7): 682-8.

O'Malley, P. M., J. G. Bachman, et al. (1988). "Period, Age, and Cohort Effects on Substance Use among Young Americans: A Decade of Change, 1976-1986." Am J Public Health **78**: 1315-1321.

Ohlander, E., M. Vikstrom, et al. (2006). "Neighbourhood non-employment and daily smoking: a population-based study of women and men in Sweden." Eur J Public Health **16**(1): 78-84.

Pentz, M. A., B. R. Brannon, et al. (1989). "The power of policy: the relationship of smoking policy to adolescent smoking." Am J Public Health **79**(7): 857-62.

Perkins, H. W., P. W. Meilman, et al. (1999). "Misperceptions of the norms for the frequency of alcohol and other drug use on college campuses." J Am Coll Health **47**(6): 253-8.

Pinilla, J., B. Gonzalez, et al. (2002). "Smoking in young adolescents: an approach with multilevel discrete choice models." J Epidemiol Community Health **56**(3): 227-32.

Reither, E. N., R. M. Hauser, et al. (2009). "Do birth cohorts matter? Age-period-cohort analyses of the obesity epidemic in the United States." Social Science and Medicine **69**: 1439-1448.

Rinehart, C. S., L. J. Bridges, et al. (2006). "Differences Between Black and White Elementary School Children's Orientations Toward Alcohol and Cocaine: A Three-Study Comparison." Journal of Ethnicity and Substance Abuse **5**(3): 75-102.

Rountree, P. W. and R. R. Clayton (1999). "A contextual model of adolescent alcohol use across the rural-urban continuum." Subst Use Misuse **34**(4-5): 495-519.

Ryder, N. B. (1965). "The cohort as a concept in the study of social change." Am Sociol Rev **30**(6): 843-61.

Schulte Gary, S. L., L. Aultman-Hall, et al. (2003). "Consideration of driver home county prohibition and alcohol-related vehicle crashes." Accid Anal Prev **35**(5): 641-8.

Sher, K. J. (1994). Individual-level risk factors. The Development of Alcohol Problems: Exploring the Biopsychosocial Matrix of Risk. R. Zucker, G. Boyd and J. Howard. Rockville, MD, NIAAA Research Monograph No. 26, NIH Publication No. 94–3495.**:** 77-108.

Shibuya, K., M. Inoue, et al. (2005). "Statistical modeling and projections of lung cancer mortality in 4 industrialized countries." Int J Cancer **117**(3): 476-85.

Strand, T. E., C. Malayeri, et al. (2004). "Adolescent smoking and trends in lung cancer incidence among young adults in Norway 1954-1998." Cancer Causes Control **15**(1): 27-33.

Tyas, S. L. and L. L. Pederson (1998). "Psychosocial factors related to adolescent smoking: a critical review of the literature." Tob Control **7**(4): 409-20.

van Lenthe, F. J. and J. P. Mackenbach (2006). "Neighbourhood and individual socioeconomic inequalities in smoking: the role of physical neighbourhood stressors." J Epidemiol Community Health **60**(8): 699-705.

Wagenaar, A. C. and T. L. Toomey (2002). "Effects of minimum drinking age laws: review and analyses of the literature from 1960 to 2000." J Stud Alcohol Suppl(14): 206-25.

Wilcox, P. (2003). "An ecological approach to understanding youth smoking trajectories: problems and prospects." Addiction **98 Suppl 1**: 57-77.

Winship, C. and D. J. Harding (2008). "A Mechanism-Based Approach to the Identification of Age-Period-Cohort Models." American Sociological Review **36**(3): 362-401.

Yang, Y. and K. C. Land (2006). A Mixed Models Approach to Age-Period-Cohort Analysis of Repeated Cross-Section Surveys: Trends in Verbal Test Scores. Sociological Methodology. R. M. Stolzenberg. Boston, Blackwell Publishing. **36**.

Yang, Y. and K. C. Land (2008). "Age-Period-Cohort Analysis of Repeated Cross-Section Surveys: Fixed or Random Effects?" American Sociological Review **36**(3): 297-326.

Yarnold, B. M. and V. Patterson (1998). "Marijuana use among Miami's adolescents, 1992." J Health Soc Policy **10**(1): 65-79.

Yen, S. T. and A. M. Jones (1996). "Individual cigarette consumption and addiction: a flexible limited dependent variable approach." Health Econ **5**(2): 105-17.