ADOLESCENCE AS A SENSITIVE PERIOD: LONG-TERM EFFECTS OF MINIMUM PURCHASE AGE LAWS ON ALCOHOL AND DRUG USE DISORDERS

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ABBREVIATIONS:
MLPA= Minimum Legal Purchase Age
DSM-IV = Diagnostic and Statistical Manual, version IV
NLAES = National Longitudinal Alcoholism Epidemiological Survey
NESARC = National Epidemiological Survey of Alcoholism and Related Conditions

ABSTRACT:

BACKGROUND: Many studies have found that early drinking initiation predicts higher risk of later alcohol and substance use problems, but it is not known whether policies influencing the age of onset of regular drinking would affect later drinking and substance use patterns, or whether early drinking onset is simply a marker for existing vulnerability to alcohol and substance use disorders.

METHOD: We use a 'natural experiment' study design to compare the prevalence of DSM-IV alcohol and substance use disorders among adult subjects exposed to different minimum legal purchase age laws (MLPA's) in the 1970's and 1980's. The sample includes 33,869 respondents born in the US 1948-1970, drawn from two nationally representative cross-sectional surveys: the 1991 National Longitudinal Alcohol Epidemiological Survey (NLAES) and the 2001 National Epidemiological Study of Alcohol and Related Conditions (NESARC). Analyses control for gender, race, parental alcohol problems, age at assessment, and state and year fixed effects; some analyses also condition on age at drinking initiation, educational attainment, age at first marriage and age at first birth.

RESULTS: Individuals who were legally allowed to purchase alcohol before age 21 had more than 25% greater odds of a current alcohol use disorder (OR 1.27, 95% c.i. 1.15, 1.41, $p < .0001$) or substance use disorder (i.e. alcohol or illegal drug use problem) (OR 1.29, 95% c.i. 1.18, 1.42, $p < .0001$), with no apparent decline in effects with age. Purchase age effects were similar among males and females, blacks and others, persons who did or did not report having parents with alcohol problems, and respondents reporting onset of drinking before and after age 16.

CONCLUSION: Exposure to a lower minimum legal purchase age is associated with significantly higher risk of a current alcohol or other substance use disorder in middle adulthood. These findings are consistent with the hypothesis that late adolescence may be a 'sensitive period' for environmental influences on the formation of alcohol use patterns.

Introduction:

Could drinking experiences in late adolescence affect the long-term risk of alcohol and other substance use disorders? Although many US-based studies have found that individuals who start to drink at younger ages are at greater risk for alcohol and other substance-abuse problems in adulthood (eg, Hingson et al, 2006, Grant and Dawson 1997) the causal relationship remains controversial. One possibility is that early drinking may simply be a marker for genetic risk factors that increase risk of both early initiation of alcohol use, and later substance dependence (Prescott & Kendler 1999; Liu et al 2004; McGue & Ianocco 2008). However, some twin studies suggest that different environmental and genetic factors may be playing a role in alcohol use at different ages (Agrawal et al 2005, Heiman et al 2008), and secular trends in adult alcohol dependence track secular trends in age of initiation across time periods that are too short to be explained by changes in the genetic composition of the population (Grucza et al, 2008). A second possibility is that age at initiation may simply be a marker for persistent environmental factors with only short-term effects at a single point in time; a well-known example might be the price of alcohol, which could have immediate effects on patterns of alcohol use at any age (Grossman et al, 2002). A third possibility is that early alcohol initiation increases the prevalence of substance use disorders by hastening the progression to problem use. However, if this were the primary mechanism, then age at onset would probably become a less important risk factor for current substance use at older ages, as differences in age of onset come to represent a smaller proportion of cumulative drinking experience. However, the final possibility is that drinking patterns at some particular age – for example, in late adolescence - may be an environmentally

modifiable risk factor with persistent effects on later adult substance use patterns. There are several lines of evidence supporting the hypothesis that late adolescence may be a sensitive period in the development of substance use preferences. Age-specific effects could come about because late adolescent substance use may influence important life choices, including educational attainment and peer networks, which may shape the social infrastructure of adult life (Cook and Moore 2001, Kremer and Levy 2008). Sensitive periods in biological development often coincide with periods when specific physical structures are being laid down, and neuroimaging studies show that changes in the structure of brain areas responsible for executive function and self-control continue, in humans, into the early 20's (Lenroot and Giedd, 2006). There is also some evidence from animal studies that adolescent exposures to alcohol may have direct and enduring effects on neural pathways involved in response to alcohol consumption (eg, White et al 2002; Barron et al, 2005; Pautassi et al 2008). But even if drinking in adolescence had more persistent effects than drinking initiation at older ages, it is unclear whether the net effects of policies directed towards delaying alcohol initiation would be harmful or beneficial. For example, reducing alcohol use in young adulthood might shift consumption to other drugs (DiNardo and Lemieux 2001), or might reduce the opportunity for 'apprenticeship' in responsible drinking (Rehm et al 2003).

It would be difficult to conduct a randomized trial of alcohol initiation in human adolescents, but a natural experiment of this kind was created by changing minimum legal purchase age (MLPA) laws in the United States during the 1970's and 1980's. From the repeal of alcohol prohibition in 1933 until the early 1970's, most US states

maintained a mimimum legal alcohol purchase age of 21 years. When the federal voting age was lowered to 18 in 1971, many states lowered the age of majority for other activities, including alcohol purchase, as well (Wechsler & Sands, 1980). By the mid-1970's, studies were beginning to report a link between lowered drinking ages and higher rates of motor vehicle crashes among teen drivers, and by 1988, all states had established an MLPA of 21 years. A total of 29 U.S. states lowered their minimum purchase ages between 1970 and 1975, and 39 states raised these ages to 21 years between 1976 and 1988 (Table S1 and Figure S1). MLPA laws in the US are among the most widely studied substance use policies in the world, with the vast majority of previous studies investigating the effects of changing MLPA's on the frequency of heavy drinking, alcohol-related traffic crashes, crime rates and suicide rates among persons below age 21 (eg, Wagenaar and Toomey 2002; Carpenter et al 2007). Almost nothing is known about the long run effects of MLPA policies, but two studies have found that lower drinking ages were associated with higher suicide rates among 21-24 year olds (Birckmayer and Hemenway 1999; Jones et al 1992), and four studies have found that young adults exposed to lower legal drinking ages were more likely to be episodic heavy drinkers in their later 20's (O'Malley and Wagenaar 1991; Moore and Cook 1995, Pacula 1997, and Cook and Moore, 2001). So far as we know, ours is the first study to observe the effects of MLPA exposures on subjects in their 30's, 40's, and 50's.

In the present study, we use a difference in difference study design (Cook and Campbell 1979; Angrist and Pischke 2009) in two nationally-representative cross-sectional surveys to compare the current prevalence of DSMIV alcohol and substance use disorders among

'exposed' subjects who could have legally purchased alcohol before the age of 21, and otherwise similar subjects who would not have been able to legally purchase alcohol until age 21. The state-by-state variation in the timing of changes in the MLPA allow us control for state characteristics that do not vary much across time, and the two surveys – conducted ten years apart – help us to control for the effects of birth cohort and age at assessment that do not vary across state. Perhaps the greatest concern in a study design of this kind is that another social or political process, especially in the turbulent era of the early 70's, might better explain an apparent link between MLPA policies and adult substance use patterns. In the case of MLPA laws, it is possible to further narrow the field of competing explanations by comparing MLPA effects in birth cohorts that fall naturally into two contrasting periods. In the earlier wave, born 1948-1955, legal purchase ages were being lowered, and younger respondents were exposed to a more permissive drinking environment than older respondents living in the same state. In the later wave, born 1956-1970, legal purchase ages were rising, and younger subjects were exposed to a less permissive drinking environment. If higher purchase ages have similar effects in both sets of birth cohorts, then the association cannot be explained by age at assessment or by trends that moved in the same direction across both periods. In another specification check, we further limit the sample to subjects who were between 18 and 20 years old within two years of a change in state law. In this restricted sample, respondents in each state/period cell were likely to have been exposed to very similar influences from popular culture and public education. In each of these specifications, the point estimates for an MLPA effect are essentially unchanged. A final concern is that cross-state migration could lead to biased estimates if persons at greater risk for developing a

substance use disorder were more or less likely to have moved to a state with more lenient drinking age laws. The NLAES data set provides state of birth as well as state of current residence, and we find no association between alcohol or substance use disorder and cross-state migration. Our main finding is that exposure to a lower legal purchase age predicts a nearly 30% increase in the odds of having a current alcohol or substance use disorder in later adulthood, with no apparent decline with age. The effect is statistically robust, and seems to be equally observable in both men and women, blacks, Hispanics, and others, earlier and later birth cohorts, and among subjects who had already started drinking regularly before the age of 16, and among those who had not. Such findings may have important implications for developmental epidemiology and for public health policy.

Source Data:

The study sample is pooled from two large, nationally representative and publicly-available US surveys: the National Longitudinal Alcohol Epidemiological Survey (NLAES), conducted in 1991-92 (Grant et al, 1994), and the National Epidemiological Survey on Alcohol and Related Conditions (NESARC), wave 1, conducted in 2001-02 (Grant et al, 2003). Both were face-to-face surveys using similar sampling frames and survey measures, and both conducted by the U.S. Bureau of the Census under supervision of the National Institute of Alcohol Abuse and Alcoholism. NLAES sampled 42,862 subjects drawn from the adult, non-institutionalized, civilian population of the 48 contiguous United States and the District of Columbia, with over-samples of Blacks and of persons 18 to 29 years old, and provides state identifiers for both state of birth and

state of current residence. The household-response rate was 91.9 percent, and the person-response rate was 97.4 percent. NESARC interviewed 43,093 respondents drawn from a sampling frame that included adult, non-institutionalized civilians in all 50 states (plus the District of Columbia) with over-samples of Blacks and Hispanics, and of respondents aged 18 to 24 years old; the public-use version of first wave of the survey provided identifiers for state of current residence. The household response rate was 89 percent, and the person response rate was 93 percent, yielding an overall response rate of 81%. Both sampling frames included military personnel living off base and residents in non-institutionalized group quarters, such as boarding houses, shelters, and dormitories. Informed consent was obtained from all subjects, and the U.S. Census Bureau and U.S. Office of Management and Budget reviewed and approved all procedures

Both surveys were conducted using computer assisted personal interviewing (CAPI), and used versions of the Alcohol Use Disorder and Associated Disabilities Interview Schedule (AUDADIS), a fully structured diagnostic interview designed to ascertain the presence of past-year and lifetime alcohol and substance use disorders according to the Diagnostic and Statistical Manual, Fourth Edition (DSM-IV^{TM}) (Grant et al, 2001; American Psychiatric Association 1994). In the present study, past-year 'alcohol use disorders' included alcohol abuse and/or dependence, and 'substance use disorders' included abuse of or dependence on alcohol, marijuana, stimulants, cocaine, opiates, heroin, sedatives, benzodiazepines, solvents, hallucinogens, or other illegal drugs. In NLAES, 'current drinkers' were those who reported having 12 or more drinks within the past; in NESARC, 'current drinkers' were those who reported having one or more drinks

within the past 12 months. Further descriptions of methods for both surveys are available elsewhere (Grant et al 1994; Grant et al 2003). For the present study, the sample was limited to 18539 subjects from NLAES and 15,330 subjects from NESARC who were born in the United States between 1948 and 1970. For comparisons across waves, subjects were divided into cohorts born between 1948 and 1955, (who were reaching age 18 in the era when minimum purchase ages were being lowered), and cohorts born between 1956 and 1970 (who were coming of age in the era when minimum purchase ages were being raised). In our strictest matching strategy, the sample was further limited to the 18,210 subjects who had reached the age of 18, 19, or 20 within two years of an MLPA law change affecting 20 year olds.

Law coding:

We coded the month and year of changes in minimum purchase age laws, including 'grandfathering' clauses, from published sources (Wagenaar 1981-82, DuMouchel 1987, O'Malley and Wagenaar 1991, and DISCUS 1996), with some discrepancies between sources resolved by judgments based on internal evidence from these sources (see Table S1). Alternate coding decisions did not lead to any significant changes in our results. Exposures based on current state of residence could be estimated in all samples, and state of birth was reported in NLAES. To maximize agreement across coding alternatives, exposure status was summarized in a binary variable coded as '1' if the respondent could have legally purchased any form of beer, wine, or liquor in their current state of residence before the age of 21, and coded '0' otherwise, but results were similar using a continuous measure of exposure. Exposure to an MLPA under 21 varied across birth years from

about 26% for native-born residents born before 1950, to a peak of 72.9 % among those born 1959, and falling to zero among those born after 1969.

Other covariates:

All analyses controlled for gender, survey, self-identified non-Hispanic Black or Hispanic race or ethnicity, indicators for five roughly equal-population quintiles of age at assessment,(20-29, 30-34, 35-39, 40-44, and 45-54 years of age), and unordered indicators for single year of birth and either state of residence or state of birth. Some analyses also controlled for a binary indicator of parental alcohol problems, onset of own drinking before age 16, inflation-adjusted state beer taxes in effect when the subject was 18 years old, and the fraction of the state population between 18 and 20 years old when the subject was 18. Other analyses included measures representing some of the channels through which the law effects could be working. These included lifetime drinking status, age of onset of regular drinking, age of onset of weekly drinking, educational attainment, marital status, age at first marriage, whether any children, age at first child, and current personal and family income.

STATISTICAL METHODS:

Because our dependent variables were categorical indicators, we used fixed-effect logistic regression models to estimate the relative odds of a current alcohol or drug use disorder among ‘exposed’ and ‘unexposed ’ subjects. In these models, indicators for each state control for factors that vary across states but not over time, and indicators for single year of birth control for factors that vary across birth years but not across states, and

controls for five-year age categories control for linear and nonlinear effects of age at assessment.

Although estimates from logistic models can be biased when strata are sparse (Kalbfleisch and Sprott, 1970), our pooled sample sizes are large enough that nearly identical estimates and standard errors were generated by ordinary fixed effect logistic models with state indicators, and by conditional logistic models stratified by state. However, ordinary logistic models gave better convergence and the ability to use sampling weights that vary within state. In analyses restricted to individuals coming of age within two years of a law change, the models use separate indicators for early and later cohorts in each state. To take account of the correlations of legal exposures and other factors governing access to alcohol within states, all standard errors were clustered at the level of the state.

The basic structure of the logistic regression model is:

$$Ln(R/1\text{-}R)_i = \alpha + b_1X_{1i} + ... + b_nX_{ni} + b_{mpla}MLPA_{stx} + \varepsilon_i$$

where R is the probability of a current alcohol or substance use disorder for individuals with a vector of characteristics $X_i ... X_n$ that always includes survey, gender, ethnicity, and unordered indicators of state of residence, age group, and year of birth. The basic models also included interaction terms between state and a linear measure of birth year, to further control for linearly changing state-specific time trends. “Long” models included other control variables, including family history of alcohol problems and own onset of regular drinking before age 16, and state beer taxes when the respondent was 18, and sometimes

included variables – such as educational attainment – that might be in the causal pathway between legal purchase age and later substance use problems. Age-restricted models were limited to respondents living in the 39 states with changing MLPA laws, and included separate indicators for early and later cohorts for each state. The coefficient of interest is b_{mlpa}, which captures the average effect of legal purchase age on the likelihood of the outcome of interest, after controlling for state of residence, age at assessment, and other variables in the model. 95% confidence intervals with two-sided p-values are reported throughout. All analyses were conducted in STATA v.10, using 'robust' standard errors clustered by state; these adjust for the correlation of observations within state, and capture most of the clustering of observations generated by the complex survey design. (Liang and Zeger, 1986; Arellano 1987).

RESULTS:

Sample description:

Table 1 describes the combined NLAES/NESARC samples. Subjects ranged from 20 to 44 years old at the time of the NLAES interview, and from 30 to 54 years old at the time of the NESARC interview. 10.3 % of the sample met DSM-IV criteria for past-year alcohol use disorder, and 11.3% met DSM-IV criteria for past-year substance use disorder. 51.6% of the full sample and 77.7% of the age-restricted sample would have been legally allowed to purchase alcohol before the age of 21. The age-restricted sample was more likely to have been exposed to a lower drinking age, more likely to be black and more likely to have a parent with an alcohol problem compared to the full sample.

Prediction from MLPAs to age of onset:

Lower legal purchase ages were associated with earlier age at onset of drinking. In ordinary and multinomial logistic regressions, we found that lower purchase age predicted that significantly more respondents would report starting to drink between 16 and 18 (OR 1.12 , 95% ci 1.01, 1.26 , p = .04), and fewer would report starting to drink at age 19 or 20 (OR .88, 95% ci .75, .1.04, p = .14) or at age 21 (OR .67, 95% c.i.56 to .82, p <.0001), Lower purchase age had no significant effect on the likelihood of drinking before age 16 (OR 1.00, 95% ci .91, 1.10, p=.98), on the likelihood of lifetime abstention (OR 1.00, 95% c.i. .90, 1.12, p = .97) , or the likelihood of drinking onset after age 21, (OR .95, 95% ci .81, 1.11, p = .50).

Prediction from MLPA exposure to mid-life alcohol and substance use disorders:

Figure 1 illustrates our core results, using raw estimates from the 18817 subjects who were coming of age within two years of a law change. The figure shows that subjects exposed to a lower drinking age were more likely to have a current DSM-IV alcohol or substance use disorder, and that these effects seem more pronounced after age 30. Tables 2 and 3 quantify these associations, controlling for state and birth year fixed effects, age at assessment, state linear time trends, gender and ethnicity. In Table 2, respondents exposed to a lower MLPA were significantly more likely to have a current alcohol use disorder (Model 1: OR 1.27; 95% c.i. 1.15 to 1.41, p< .0001). There were no significant interactions between exposure status and gender, ethnicity, survey, age at assessment, early or later birth cohort, or parental history of alcohol problems, and estimates were little changed by inclusion of state beer taxes at age 18, educational attainment, current

marital status, age at first marriage, current parenthood status, age at first child, and family income. The results were similar when the sample was restricted to subjects who were coming of age within two years of a law change (Table 2, models 3 and 4), and in models predicting current substance use disorder (Table 3).

Similarity of MLPA effects among early- and later-onset drinkers.

Even though MLPA exposure did predict age of onset of drinking, the association between MLPA exposure and alcohol or other substance use disorder did not seem to be working through age of onset of drinking, per se. MLPA effect estimates were nearly identical among 'early drinkers' – respondents who had started to drink before age 16 (n= 3978, OR 1.29, 95% c.i. .94, 1.76, p =.11) - and among later drinkers, who had not yet started to drink by age 16 (n = 29,891, OR 1.27, 95% c.i. 1.11, 1.45, p< .0001). Linear estimates were little changed by the inclusion of abstention status or age of drinking onset in the regression model (eg, Table 2, Model 2: OR 1.27, 95% c.i. 1.14,1.42; p < .0001), or by inclusion of age of onset of weekly drinking.

MLPA's and cross-state migration:

Finally, we tested whether cross-state migration could be a confounder of the apparent purchase-age effect, using state of birth information in NLAES and the 1990-2000 US Census. In neither sample was law exposure a significant predictor of cross-state migration (eg, in Census, the odds of migration given exposure status based on state of birth yielded an OR of 1.01, 95% c.i. .99, 1.04, p = .27). Furthermore, in the NLAES

sample, migration status was not a significant predictor of current alcohol or substance use disorder (eg, for substance use disorder: OR= 0.97; 95 % ci .89, 1.07; p = .58).

DISCUSSION:

MLPA laws in the US are now among the strictest in the world, and they are still controversial, but the vast majority of previous studies have found that changing MLPA's did affect the frequency of heavy drinking, alcohol-related traffic crashes, and suicide among persons below age 21. Almost all prior studies have focussed only on outcomes in young adulthood, but in the present study, we find that exposure to a legal purchase age of less than 21 increased the odds of a current alcohol or other substance use disorder among adults aged 21-54 by almost 30%. The estimates were similar for all subgroups examined, were separately significant for respondents who had started to drink before age 16 or not, and did not diminish with age.

It has been suggested that stricter MLPA laws might lead young adults to switch from alcohol to marijuana or other substance use. alcohol and other drugs could be substitutes. For example, Chaloupka and Laixuthai (1997) found that marijuana decriminalization increases marijuana use, decreases alcohol use and lowers the rate of youth traffic crashes, and DiNardo and Lemieux (2001) found that stricter minimum drinking age laws seem to increase marijuana use. However, other short-run studies, including Pacula (1998) and Saffer and Chaloupka (1999) find that increases in beer taxes or legal drinking ages led to decreases in marijuana use. In the present study, we found similar effects of MLPA exposure for both alcohol and other substance use disorders, suggesting that in the

long run, stricter drinking age laws lead to a net decrease in other drug use problems in later adulthood.

Multiple possible channels for a 'sensitive period':

These surprisingly strong results suggest that alcohol-related experiences in adolescence may have persistent effects on substance use patterns in adults in their 30's, 40's, and 50's. Age-specific associations between early drinking exposure and later alcohol use disorders could come about through multiple channels. First is the possibility that adolescent alcohol use might help to shape the social infrastructure of adult life, including educational attainment, peer networks, mate choice, and family formation - all factors which may then influence the risk of later alcohol use disorders. However, it seems unlikely that these effects were working through age of onset of drinking, per se. The estimates were nearly unchanged in models that included lifetime abstention status, age of initiation of drinking, or age of initiation of weekly drinking, and were similar and separately significant among subjects who had already started to drink by the age of 16 and those who had not. The estimates were also unchanged in models controlling for commonly-cited demographic pathways that might link alcohol use and later outcomes, including educational attainment, marriage, parenthood, and employment status. A plausible alternative is that minimum purchase age effects could be working through 'social multipliers' – including public education and peer effects - not directly measured in the NLAES and NESARC surveys. For example, if young adults prefer to drink with friends than to drink alone, then even among individuals who had already started to drink before legal age, a more restrictive purchase age could limit the pool of available young

drinking companions, and could therefore have decisive influences on the frequency, activities, and social composition of the encounters around which people form enduring social relationships (Glaeser et al, 2003; Kremer and Levy, 2008).

Treatment heterogeneity:

Estimation of the average policy response for the overall population may mask important differences across groups, and it is an empirical question whether the effects of an environmental intervention are larger or smaller in higher-risk groups. In the present study, we found similar and separately significant results among respondents who had started to drink before the age of 16, and among those who had not, and among those with a family history of alcoholism and among those who did not.

Competing explanations:

The 1970's were a turbulent era, and MLPA laws were not the only social processes that might have affected lifetime patterns of alcohol and other substance use for cohorts coming of age in this period. There were changes in political and social culture, the demographic influence of a large birth cohort, changes in the legal and economic status of women and ethnic minorities, overall changes in public education and social attitudes towards drugs and alcohol use, and probable changes in law enforcement. Never the less, we have greatly narrowed the range of possible explanations by comparing cohorts coming of age in the 1970's (when drinking ages were being lowered) and in the 1980's (when drinking ages were being raised again); and by comparing state cohorts closely matched in age. Even if the apparent MLPA effects are not attributable to changing

drinking-age laws themselves, our findings suggest that late adolescence may be a 'sensitive period' for a social trend closely tied to the timing of these changing laws.

Limitations:

There are several other limitations to the present study. First, there are the usual problems associated with retrospective surveys, including reporting biases, and limited information about details of exposure status such as timing of law changes, strictness of policy enforcement, and cross-state moves. However, the consistency of our results across age at assessment, survey, gender, ethnicity, family background, and statistical approach provide reassurance about the believability of our findings. There were important limitations to our measures of exposures and outcomes; for example, we did not have a direct measure of alcohol use between the ages of 18 and 21, and our measures of MLPA exposure do not account for cross-state variations in policy enforcement, and cross-state differences in the opportunity for underage drinkers to legally purchase alcohol in other nearby states. However, these 'reduced form' analyses do provide an estimate of the average effects of changing MLPA exposures across the United States, as they were actually implemented across states and years. Although selection bias is a potential concern in any survey, the response rates for NLAES and NESARC were high, and comparisons with the US Census suggest that sampling frame and cross-state migration were unlikely to be important confounders of purchase age exposure in our analyses; however, cross-state migration probably introduces some measurement error that will lead us to under-estimate the true effects of MLPA exposure in the affected cohorts.

CONCLUSION:

This is the first study to document a long-term association between policies governing access to alcohol in young adulthood, and risk of substance use disorders in later adulthood. We find that adults who would have been legally allowed to purchase alcohol before age 21 were significantly more likely to have a current alcohol or drug use disorder than adults who could not legally purchase alcohol until age 21 (OR 1.29, $p < .0001$), even among respondents in their 40's and 50's (OR 1.55, $p < .01$). These surprisingly strong results suggest that late adolescence may be a 'sensitive period' for an environmental exposure closely tied to the timing of these changing laws. A better understanding of the mechanism linking purchase age exposures and later alcohol and substance use problems could help to illuminate fundamental processes pertaining to adolescent development, and may point the way towards more effective preventive interventions.

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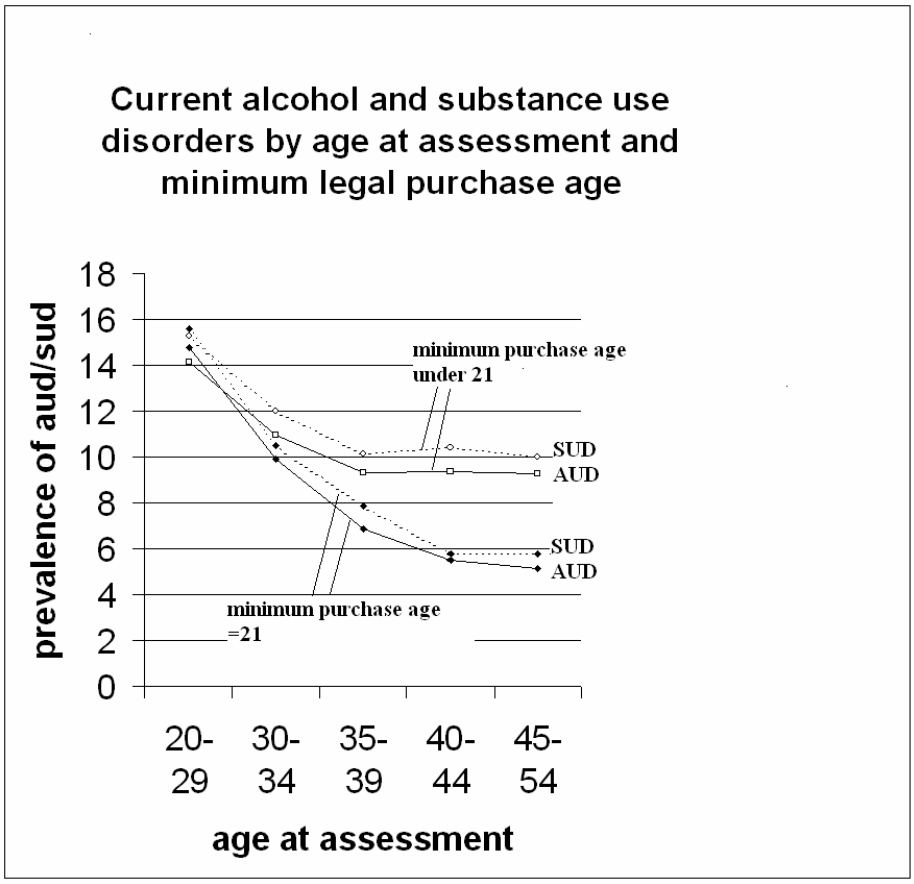

Current alcohol and substance use disorders by age at assessment and minimum legal purchase age
prevalence of aud/sud
18
16
14
12
10
8
6
4
2
0
minimum purchase age under 21
SUD
AUD
SUD
AUD
minimum purchase age =21
20-29
30-34
35-39
40-44
45-54
age at assessment

Legend Figure 1

Prevalence of past-year DSM-IV alcohol use disorder (AUD) or substance use disorders (SUD), by age group and exposure to minimum legal purchase age. Closed markers: drinking age = 21; open markers: drinking age under 21. Solid line: alcohol use disorders; dashed line: substance use disorder, including alcohol, marijuana, and other illegal drugs. N = 18212 respondents in age-restricted NLAES/NESARC sample coming of age within 2 years of law change.

Table 1: Sample Description:

	Full sample	Age-restricted sample[a]
N	33,869	18,212
Interview year	1991-2002	1991-2002
Mean Birth year (SD)	1958.0 (6.4)	1957.8 (5.9)
Mean Age at interview (SD)	39.5 (7.9)	39.7 (7.5)
Sex (%)		
Female	51.0	51.2
Male	49.0	48.8
Race (%)		
Non-hispanic Black	12.8	13.7
Hispanic	5.0	3.9
Non-black, non-Hispanic	82.4	82.5
Education (%, Highest Completed)		
No High School	9.4	9.3
High school	61.9	61.9
College	28.7	28.8
Marital Status (%)		
Ever married	81.3	83.3
Never Married	18.7	16.7
Mean Age at first marriage (SD)[b]	23.1 (6.9)	23.9 (7.1)
Parenthood		
Ever had a child	64.9	67.7
Never had a child	35.1	32.3
Mean Age at first birth (SD)[c]	24.9 (5.5)	24.1 (5.5)
Substance Use and Disorder (%)		
Past year AUD	10.3	10.2
Past year SUD	11.3	11.6
Onset drinking before age 16	12.3	12.2
Lifetime Abstainer	16.5	15.8
Parent had alcohol problem	28.2	27.8
Risk Factor Exposure, All subjects:		
MLPA < 21, state of residence	51.6	77.7
Risk Factor Exposure, NLAES sample		
Moved from state of birth [d]	36.9	38.7
MLPA < 21, state of birth [d]	49.9	68.2
Switched MLPA status [d]	16.2	16.9

Note: 'MLPA'= Minimum Legal Purchase Age; coded 1 if responded could have legally purchased alcohol before age 21. Data source = subjects born in US 1948-1970, pooled from the 1991-1992 National Longitudinal Alcohol Epidemiological Survey (NLAES), and the 2001-2002 National Epidemiological Survey of Alcoholism and Related Conditions (NESARC). [a]Respondents who were aged 18, 19, or 20 within two years before or after a change in MLPA law in state of residence. [b]Married subjects only. [c]Respondents with children only. [d] NLAES only.

Table 2:

Minimum Legal Purchase Age Exposure and Current Alcohol Use Disorder

	Full Sample (N=33,869)		Age-restricted Sample (N=18,209)	
	Model 1	Model 2 [a] with other covariates	Model 3	Model 4[a] with other covariates
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
N	33,869	33,869	18,212	18,212
Exposure				
MLPA<21	1.27 (1.15, 1.41)****	1.27 (1.14,1.42)****	1.26 (1.03, 1.55)*	1.28 (1.04, 1.57)*
Age group:				
Age 30-34	0.61 (0.45, 0.83)***	0.61 (0.44, .84)**	0.69 (0.49, .98)*	0.67 (0.46, 0.98)
Age 35-39	0.70 (0.48, 1.03)	0.73 (0.49, 1.11)	0.67 (0.40, 1.10)	0.67 (0.40, 1.12)
Age 40-44	0.66 (0.37, 1.17)	0.69 (0.37, 1.29)	0.65 (0.28, 1.47)	0.65 (0.28, 1.51)
Age 45-54	0.87 (0.41, 1.85)	0.94 (0.42, 2.16)	0.74 (0.28, 1.92)	0.77 (0.29, 2.04)
Survey				
NESARC	0.96 (0.71, 1.31)	0.83 (0.59,1.17)	1.15(0.74, 1.79)	1.00 (0.63, 1.57)
Sex				
Female	0.37 (0.34, 0.41)****	0.43 (0.39, 0.47)****	0.36 (0.32, 0.41)****	0.42 (0.37, 0.47)****
Race/Ethnicity				
Black	0.79 (0.68, 0.91)****	1.06 (0.92, 1.22)	0.88 (0.73, 1.05)	1.15 (0.96, 1.37)
Hispanic	0.85 (0.66, 1.10)	0.95 (0.69, 1.23)	0.78 (0.49, 1.51)	0.86 (0.49, 1.49)

Notes: Odds ratio given in table, with 95% confidence interval in parentheses

Each column gives the result of one fixed-effect logistic regression. 'MLPA'= Minimum Legal Purchase Age; coded 1 if responded could have legally purchased alcohol before age 21. Data source = respondents born in US 1948-1970, pooled from the 1991-1992 National Longitudinal Alcohol Epidemiological Survey (NLAES), and the 2001-2002 National Epidemiological Survey of Alcoholism and Related Conditions (NESARC). All models include indicators of state of residence and single year of birth as covariates. Age-restricted sample limited to respondents coming of age within 2 years of change in minimum legal purchase age law. Omitted categories are MLPA=21(exposure), NLAES (survey), male (sex), agegroup 20-29 (age) and non-Black, non-Hispanic (ethnicity). [a]Models 2 and 4 also include parental history of drinking problems, onset of own drinking before age 16, age of onset of drinking, and lifetime abstention status as covariates.

# p < .10 *p<.05 **p<.01 ***p<.001 ****p<.0001

Table 3:

Minimum Legal Purchase Age Exposure and Current Substance Use Disorder

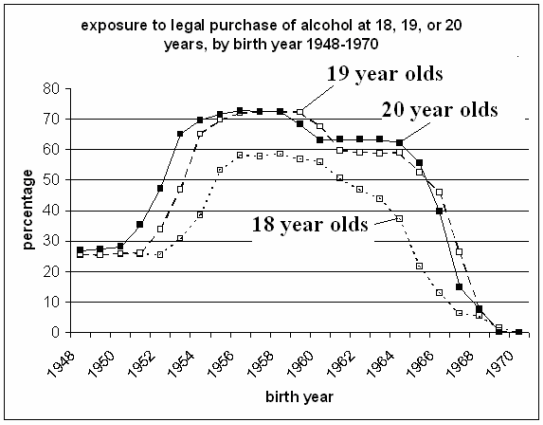
	Full Sample (N=33,869)		Age-restricted Sample (N=18,209)	
	Model 1	Model 2[a]	Model 3	Model 4[a]
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
N	33,869	33,869	18,212	18,212
Exposure				
MLPA<21	1.29 (1.18, 1.41)****	1.30 (1.17, 1.43) ****	1.24 (1.03, 1.49)*	1.26 (1.04, 1.52)*
Age group:				
Age 30-34	0.65 (0.49, 0.86)**	0.65 (0.48, 0.89)**	0.68 (0.48, 0.97)*	0.67 (0.45, 0.99)*
Age 35-39	0.77 (0.54, 1.09)	0.81 (0.55, 1.19)	0.68 (0.42, 1.11)	0.69 (0.41, 1.15)
Age 40-44	0.73 (0.42, 1.26)	0.78 (0.43, 1.40)	0.67 (0.29, 1.51)	0.68 (0.29, 1.60)
Age 45-54	0.96 (0.46, 2.00)	1.06 (0.47, 2.35)	0.77 (0.29, 2.04)	0.81 (0.29. 2.23)
Survey				
NESARC	0.92 (0.68, 1.25)	0.80 (0.57, 1.12)	1.12 (0.72, 1.75)	0.97 (0.61, 1.55)
Sex				
Female	0.39 (0.36, 0.41)****	0.44 (0.41, .48)****	0.38(0.33, .42)****	0.43(0.38, .48)****
Race/Ethnicity				
Black	0.82 (0.70, 0.93) **	1.08 (0.94, 1.24)	0.88 (0.73, 1.07)	1.15 (0.95, 1.38)
Hispanic	0.83 (0.65, 1.06)	0.91 (0.69, 1.20)	0.75 (0.47, 1.19)	0.81 (0.47, 1.38)

See notes for Table 2. Odds ratio given in table, with 95% confidence interval in parentheses

# p < .10 *p<.05 **p<.01 ***p<.001 ****p<.0001

SUPPLEMENTARY TABLES:

Figure s1



Legend, Figure S1

Proportion of US-born birth cohorts 1948-1970 who would have been legally permitted to purchase alcohol at ages 18, 19, or 20 in their current state of residence. Based on current state of residence in 1% sample from US Censuses, 1990 and 2000; minimum legal purchase age laws coded as described in text. Some cohorts were able to purchase alcohol at age 19 but not at age 20 because of more restrictive drinking age laws implemented between 1976 and 1988. N = 1,605,320. Exposure to a minimum legal purchase age of less than 21 varied from about 26% among native-born residents born before 1950, to a peak of about 73 % among those born 1955 to 1960, and falling to zero among those born after 1969.

CHECK DATES BEFORE 1970

Table S1: Minimum Legal Purchase Age laws, 1933-1988

State name	*Start date* Any legal purchase under age 21	*Last date* Any legal purchase under age 21	Grandfathering clauses[a]
Alabama	7/22/1975	9/30/1985	19 or older before 10/1/1985
Alaska	9/1970	10/26/1983	19 or older if born on or before 12/31/1964
Arizona	8/1972	12/31/1984	19 or older before 12/31/1984
Arkansas[b]	--	--	--
California[b]	--	--	--
Colorado	8/1933	7/30/1987	19 or older by 7/30/1987
Connecticut	10/1972	8/31/1985	20 by 9/1/1985
Delaware	7/1972	12/31/1983	20 by 1/1/1984
District of Columbia	2/1934	9/30/1986	18 by 9/30/86
Florida	7/1973	6/30/1985	19 or older if born on or before 6/30/1966
Georgia	7/1972	9/29/1986	--
Hawaii	3/1972	9/31/1986	--
Idaho	7/1972	4/10/1987	19 on or before 4/10/1987
Illinois	10/1/1973	12/31/1979	--
Indiana[b]	--	--	--
Iowa	4/1972	9/1/1986	19 on or before 9/1/1967
Kansas	5/1937	7/1/1985	19 on or before 7/1/1985
Kentucky[b]	--	--	--
Louisiana	11/1948	3/15/1987	18 if born on or before 9/30/1967
Maine	10/1/1969	6/30/1985	20 before 7/1/1985
Maryland	7/1/1974	6/30/1982	18 if born before 7/1/1964
Massachusetts	3/1/1973	5/31/1985	20 before 6/1/1985
Michigan	2/19/1972	12/20/1978	--
Minnesota	6/1973	8/31/1986	19 before 9/1/1986
Mississippi	2/1934	9/30/1986	--
Missouri[b]	--	--	--
Montana	7/1971	3/31/1987	19 if born before 4/1/1968
Nebraska	5/1933	12/31/1984	20 by 1/1/1985
Nevadab	--	--	--
New Hampshire	6/3/1973	5/31/1985	20 by 6/1/1985

New Jersey	1/1973	12/31/1982	18 before 1/2/80 19 before 1/1/83
New Mexico[b]	--	--	--
New York	5/1934	11/30/1985	--
North Carolina	4/1933	8/31/1986	--
North Dakota[b]	--	--	--
Ohio	4/1933	7/30/1987	19 or older by 7/31/1987
Oklahoma	7/1933	9/21/83	--
Oregon[b]	--	--	--
Pennsylvania[b]	--	--	--
Rhode Island	3/1972	6/31/1984	--
South Carolina	4/1933	9/14/1986	--
South Dakota	8/1933	3/31/1988	--
Tennessee	5/1971	7/31/1984	19 if born before 8/1/1965
Texas	8/1973	8/31/1986	--
Utah[b]	--	--	--
Vermont	11/71	6/30/1986	18 by 6/30/1986
Virginia	7/7/1974	6/30/1985	19 by 7/1/1985
Washington[b]	--	--	--
West Virginia	4/1935	6/30/1986	18 by 7/1/1983
Wisconsin	4/1933	9/2/1986	18 before 7/1/1984 19 by 9/1/86
Wyoming	5/1973	7/1/1988	--

Notes:

a:‘grandfathering clause’ indicates that persons of specified age were allowed to continue to legally purchase some forms of alcohol before 21st birthday. Sources: Weschler and Sands 1980; Wagenaar 1981/1982; DuMouchel, Williams, and Zador 1987; O’Malley and Wagenaar 1991; NIAAA 2008 [21-25]

b: these states had a minimum legal purchase age of 21 years throughout period

TABLE S2: Effect of Minimum Purchase Age Exposure on Current Alcohol and Substance Use Disorders, By Age at Assessment. N=33,869

	Model 1	Model 2
	Current Alcohol Use Disorder	Current Substance Use Disorder
	OR (95% CI)	OR (95% CI)
Exposure		
MLPA*age 20-29	1.09(0.91, 1.30)	1.15 (0.96, 1.36)
MLPA*age 30-34	1.42(1.12, 1.78)**	1.45 (1.18, 1.78)****
MLPA*age 35-39	1.28(1.08, 1.52)**	1.22 (1.05, 1.43)*
MLPA*age 40-44	1.23(1.00, 1.51)*	1.25 (1.02, 1.54)*
MLPA*age 45-54	1.50(1.09,2.08)*	1.55 (1.17, 2.05)**
Age		
Age 30-34	0.51 (0.35, 0.74)****	0.55 (0.38, 0.78)***
Age 35-39	0.56(0.36, 0.88)*	0.66 (0.42, 1.02)#
Age 40-44	0.52 (0.27, 0.98)*	0.59 (.32, 1.08) #
Age 45-54	0.55 (0.21, 1.41)	0.62 (0.25,1.52)
Survey		
NESARC	1.11 (0.79, 1.55)	1.05 (0.75,1.47)
Sex		
Female	0.37 (0.34, 0.40)****	0.39 (0.36, 0.41)****
Race/Ethnicity		
Black	0.79 (0.68, 0.91)****	0.82 (0.71, 0.93)**
Hispanic	0.85 (0.66, 1.10)	0.83 (0.65, 1.06)

Notes: Odds ratio given in table, with 95% confidence interval in parentheses. See notes for table S4

# p < .10 *p<.05 **p<.01 ***p<.001 ****p<.0001.